

GEOGRAPHIC INFORMATION SYSTEMS IN THE APPLICATION OF  
PRECISION AGRICULTURE FOR SUSTAINABLE SUGARCANE  
PRODUCTION IN THE REPUBLIC OF PANAMA

by

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## **ABSTRACT**

Geographic Information Systems (GIS) have revolutionized the development of the sophisticated resource management method known as Precision Agriculture (PA). PA involves the wise management of agricultural inputs based on knowledge of soil and plant health heterogeneity over a field, in order to minimize environmental impact and increase economic efficiency. A GIS platform was created as the basis of PA implementation at Azucarera Nacional sugarcane plantation in Panama. Field data collection took place over two years, from 2005 to 2006. A digital map of Mangote plantation was created and linked to production records. Detailed field sampling was also conducted on seven parcels of Mangote plantation, including soil conductivity monitoring and plant chlorophyll monitoring. Data was spatially interpolated to create raster coverages.

Soil salinity variation within some parcels studied justifies the creation of soil salinity management zones. Salinity zones were found to be relatively stable over the study period and in general conductivity at a depth was higher than at the surface. The root mean square errors obtained using Inverse Distance Weighting as opposed to Ordinary Kriging did not vary greatly, and hence it is recommended to use the simpler method (IDW) at the study site. Plant chlorophyll profiles revealed nitrogen deficiencies in some study parcels. Plant chlorophyll also showed within parcel variability as well as variability over the study period. No direct spatial correlation was found between conductivity readings and plant chlorophyll readings, although parcels with extreme salinity showed depressed chlorophyll values. The ground-based chlorophyll sampling showed no correlation with NDVI, however the NDVI coverages were deemed useful for the visual identification of plant stress. In general, GIS based management shows promise in improving Azucarera Nacional's agricultural efficiency.

## RÉSUMÉ

Les systèmes d'information géographiques (SIG) a révolutionné l'élaboration de la méthode sophistiquée de gestion connue sous le nom d'agriculture de précision (AP). L'AP implique la gestion sage des entrées agricoles basées sur la connaissance de l'hétérogénéité de santé de sol et des récoltes dans un champ, afin de réduire au minimum les impacts sur l'environnement et augmenter l'efficacité économique. Une plateforme de SIG a été créée comme base d'exécution de AP à la plantation de canne à sucre d'Azucarera Nacional au Panama. La collection de données a eu lieu sur deux ans, de 2005 à 2006. Une carte digitale de la plantation Mangote a été créée et liée aux dossiers de production. Le prélèvement de données dans le champ a été conduit sur sept champs particuliers de la plantation Mangote, quel incluse une enquête de conductivité de sol et des mesures de chlorophylle. Des données ont été interpolées pour créer des surfaces continues.

La variation considérable de salinité de sol dans quelques champs étudiés justifie la création des zones de gestion de salinité de sol. Des zones de gestion de salinité sont relativement stables au cours de la période d'étude et en général la conductivité à une profondeur est plus haute que sur la surface. Les erreurs quadratiques moyenne obtenues en utilisant IDW, en comparaison avec OK, n'ont pas changé considérablement et par conséquent on lui recommande l'IDW comme l'option le plus simple. Les profils de chlorophylle ont indiquées insuffisances d'azote pour quelques champs. Les profils de chlorophylle ont également montrée la variabilité dedans les champs, aussi bien que la variabilité au cours de la période d'étude. Aucune corrélation directe n'a été trouvé entre les lectures de conductivité et les lectures de chlorophylle bien qu'en général les champs avec la salinité extrême aient montré des valeurs diminuées de chlorophylle. Le système de prélèvement pour surveillance du contenu de chlorophylle n'a montré aucune corrélation avec NDVI, toutefois le NDVI est considérée utiles pour l'identification visuelle de santé végétale. Généralement l'intégration de SIG est prometteuse en améliorant l'efficacité agricole d'Azucarera Nacional.

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## LIST OF ACRONYMS AND SYMBOLS

|       |                                                              |
|-------|--------------------------------------------------------------|
| CSIRO | Commonwealth Scientific and Industrial Research Organization |
| ESRI  | Environmental Systems Research Institute                     |
| DGPS  | differential global positioning system                       |
| GIS   | Geographic Information Systems                               |
| GPS   | Global Positioning Systems                                   |
| ha    | hectare                                                      |
| IDW   | inverse distance weighting                                   |
| IRSS  | Indian Remote Sensing Satellite                              |
| m     | meter                                                        |
| MSAVI | modified soil adjusted vegetation index                      |
| NDVI  | normalized difference vegetation index                       |
| NSERC | natural science and engineering research council             |

|      |                                                               |
|------|---------------------------------------------------------------|
| OK   | Ordinary Kriging                                              |
| OKTR | Ordinary Kriging with trend removed                           |
| PA   | precision agriculture                                         |
| R    | correlation coefficient                                       |
| RMSE | root mean square error                                        |
| RS   | remote sensing                                                |
| SASA | South African Sugarcane Association                           |
| SAVI | soil-adjusted vegetation index                                |
| SPAD | specialty products agricultural division, Minolta Corporation |
| VRT  | variable rate technology                                      |

## CHAPTER 1 INTRODUCTION

“There is no global challenge facing humanity that is more important than managing the earth’s environment to assure that it can sustain life in all its forms” (FAO 2007).

### 1.1 Motivation

There exists an important and pressing need to ensure food security as global population increases (USAID, 2007). Furthermore, not only ample but *sustainable* crop production is crucial to relieve the tremendous pressure on natural resources that corresponds to this increase (FAO, 2006). The importance of wise management of freshwater resources, prudent use of pesticides and fertilizers, and the mitigation of soil erosion are prime concerns, not only for the agricultural sector, but also for the global community (GEF, 2006). Cutting-edge spatial information technologies such as Geographic Information System (GIS), Global Positioning System (GPS), satellite remote sensing (SRS), and digital image processing (DIP) are invaluable tools in the accomplishment of these goals and provide a backbone for the burgeoning field of precision agriculture (PA) (Brisco et al., 1998).

Precision agriculture, also known as site-specific farming, is a management scheme which aims to *optimize* crop land use by increasing production, while decreasing agricultural inputs. This dual goal addresses the issue of human subsistence while accounting for the environmental repercussions of agriculture which are derived mainly from its inputs; that is, the excessive use of freshwater and agro-chemicals which effect surrounding ecosystems. Although the theory supporting PA has been around for centuries, the enlargement of fields and intensive mechanization that are the hallmarks of modern agriculture, have made sophisticated ‘on-the-go’ site-specific management unrealistic without an accompanying revolutionary development in technologies (Zhang et al., 2002). These spatial information technologies, particularly SRS and GIS, have begun to play an increasingly important role in environmental monitoring and resource management activities in general, and are at the heart of PA implementation.

Although the acceptance and growth of PA has been rapid, some fundamental requirements are needed to help fully develop and implement this technology on a larger

scale (Brisco et al., 1998). Not only is there a need for further research into the various technical aspects of PA, but a paradigm shift must also occur in agricultural production towards sustainability. Not surprisingly, countries of the global south often face additional challenges in regards to PA implementation. Despite the on-going development of PA related tools for tropical crops such as sugarcane in Brazil, Australia and South Africa, widespread dissemination remains largely unrealized. Unfortunately, issues related to lack of access to appropriate resources, and the current capital cost and delayed return on investment associated with PA implementation are the greatest deterrents to developing countries that would potentially derive the greatest benefits from adoption (Cook et al., 2003).

In order to overcome the barriers mentioned above, certain key developments must occur:

- 1) Place emphasis on the economic value of information gathering and environmental externalities
- 2) Develop and implement training and technology transfer programs to accelerate the acceptance of this technology for the agribusiness sector, especially in developing countries
- 3) Increase access to satellite imagery and develop straightforward methods of satellite image analysis for practical crop management purposes

Contributing to a solution for the problems listed above, in the particular regional context of the Panamanian sugarcane industry by establishing a platform GIS, is the principle motivation for this project. With agricultural activities as the primary economic activity in Latin America (FAO, 2005) and the presence of some of the world's largest cane producers (Brazil, Cuba etc.) often subjected to limited or no environmental regulations, the project was initiated in the hopes of promoting regional development of sustainable agricultural practices by developing a practical tool and generating thematic maps to help farmers improve:

- 1) Irrigation management to mitigate salinization
- 2) Fertilizer management to mitigate waste.

With the participation of the Universidad Tecnológica de Panamá, this project was carried out as a consultation contract with Azucarera Nacional and the accompanying

dissertation was prepared under the Neotropical Environment Option offered jointly by McGill University and the Smithsonian Tropical Research Institute (STRI).

## **1.2 Background**

### **1.2.1 Sugarcane**

The Latin America and the Caribbean region has undergone significant land use changes in the past few decades, with tremendous expansion of cultivated area of three principal crops: soybeans, corn and sugarcane (Tejo and Nagel, 2002). Concurrently, Panamanian farm production has undergone a major change in the last few decades, with predominant agricultural activities such as banana cultivation declining and crops such as coffee and sugarcane increasing their share of the total agricultural GDP (Tejo and Nagel, 2002). Sugarcane producers however, have had to contend with the cut on import quotas that the United States has imposed on Panama, making profitable sugarcane production an increasingly difficult task (Tejo and Nagel, 2002). In addition to this, all sugar industries are being exposed to the low world price for sugar or are otherwise facing reduced income from sugar exports and hence are feeling the pressure of reduced viability (Milford, 2005). In order for the Panamanian sugar industry to survive and compete on the international market in the face of these pressures, measures must be taken to increase production efficiency and stay abreast with modern agricultural developments.

Sugarcane is an extremely valuable agricultural resource from which sugar and a variety of by-products are derived. The sugar industry processes sugarcane and sugar beet to manufacture edible sugar, with over 60% of the world's sugar production coming from sugarcane cultivation. (World Bank Group, 1998). Sugarcane is a member of the plant family *Graminae* of which only the species *Saccharum officinarum* L. is grown commercially. Economically, the most important part of the sugar cane plant is the stalk containing sucrose. The plant is harvested and processed to extract the final product sugar. Sugarcane is commonly propagated asexually, whereby mature cane is cut, producing new shoots and root systems from the underground part of the stalk. The new plant emerging after the first cut is known as the first ratoon, and successive generations

are named accordingly. The sucrose content of the sugarcane plant decreases with increasing number of ratoons, and the amount of decrease depends on regionally varying environmental conditions and the variety of sugarcane grown. Consequently, the number of ratoons common in commercial sugarcane farming varies greatly from region to region. Most varieties of cane grown at Santa Rosa are harvested up to approximately 12 ratoons.

Certain properties of the sugarcane plant with regard to commercial sugarcane farming are of major importance from the economical and social point of view. First of all, sugarcane is a perennial grass, and hence, is normally not integrated into a rotation system; it is commonly carried out as a monoculture and requires inputs of freshwater, pesticides and fertilizers. Furthermore, the fact that sugarcane is harvested by cutting the stalk and removing the leaves and tops which, if harvesting is not mechanized, is very labor-intensive. High sucrose content levels, which are attained at full maturity, only last for a relatively short period; therefore cane must be harvested within a limited period of time, making harvest labor-intensive and seasonal. Sugarcane agriculture, as with most other crops, is controlled by a complex system of environmental determinants such as climate, landform and soil. Farmers experience severe environmental constraints with regard to natural hazards that cause damage to the plant and often result in heavy yield losses. These characteristics, and the prevailing economic conditions under which sugarcane agriculture is carried out, make sustainable and optimal farming practices a particular necessity.

### **1.2.2 Study area: Azucarera Nacional, Republic of Panama**

The project site, and ultimate beneficiary of PA implementation, is Panamanian company Azucarera Nacional, the oldest and largest sugarcane producer in Panama and an important player in Panama's agricultural sector. Azucarera Nacional was founded by Mr. David Delvalle in 1884, an entrepreneur motivated by a governmental initiative promoting economic development who took the opportunity to establish the plantation in an area of the province of Coclé known as El Roble, in the Republic of Panama. The original machinery and equipment were transported in boats to the Port of Aguadulce and

then in ox-carts to Santa Rosa. In 1913, the Santa Rosa plantation realized its first zafra (sugarcane harvest), thereby starting the Panamanian national sugar industry.

The current land holdings of Azucarera Nacional span over 15,000 hectares in the provinces of Coclé and Herrera. The plantation is also situated in the heart of the Santa Maria watershed and uses water from the Santa Maria River for irrigation during the dry season which goes from December to April and rain-fed irrigation during the remainder of the year. The company holdings are comprised of five farms: Santa Rosa, Panela, Mangote, Los Canelos and San Jose. Small independent sugarcane producers or Colonos also provide a significant portion of the cane that is processed by the on-site sugar mill. Each farm is composed of smaller parcels of land which range in size from just a few hectares to over 30 hectares. The parcels are the functional production units for each farm, and all agricultural inputs are applied on a parcel basis. For the purposes of this project, mapping was restricted to the Mangote farm and detailed studies were carried out on several individual production units, or parcels, on Mangote. Implementation of PA at this site represents an important step in the Panamanian governmental mandate to increase efficiency and sustainability in agriculture and also represents an important step in the dissemination of PA technologies in the region.

### **1.3 Hypothesis**

The current project is based on the assumption that GIS is an important tool in site-specific management and that such a management scheme can greatly contribute to the sustainability of agricultural activities. Furthermore, it is based on the assumption that soil conductivity heterogeneity and plant chlorophyll heterogeneity over a field are important parameters to monitor to optimize agricultural inputs. The hypothesis is that using GIS and creating maps which display soil and plant health properties, by using spatial interpolation to predict values at un-sampled locations, in conjunction with remote sensing information, is expected to result in more complete estimation of in-field heterogeneity and that this information can be used to optimize farm operations.



## 1.4 Objectives

The principal objective of this project is to establish a platform GIS in order to initiate a PA management scheme at Azucarera Nacional. In order to fulfill this objective, it is necessary to first build a digital cartographic base and then add information to the system that can eventually be used for analysis of conditions in individual fields, or parcels and for optimization of operations. Finally, capacity-building in data collection and GIS analysis, as well as effective technology transfer, are significant priorities of this project. The specific objectives are:

1. Create an annotated digital land holdings map for the Mangote plantation of Azucarera Nacional.
2. Create descriptive maps of Mangote based on variations between individual parcels of the following parameters:
  - i) Production
  - ii) Ratoon number
3. Create maps of individual study parcels of Mangote using ground-truth and soil sample analysis data describing variations in:
  - i) Soil conductivity and changes over time and with depth
  - ii) Plant chlorophyll
4. Compare the performance of inverse distance weighting and ordinary kriging for predicting the spatial variability of soil properties
5. Investigate the utility of multispectral high-resolution satellite imagery in the visual identification of plant stress and correlation of NDVI with SPAD meter plant chlorophyll measurements

In order to meet these general and specific objectives information from aerial photography and hard copy maps were integrated to create a digital map of Mangote plantation of Azucarera Nacional in Panama. This was carried out in conjunction with extensive field scale studies of seven individual study parcels of Mangote over two consecutive years (2005 and 2006). Remote sensing data was also acquired from the Quickbird satellite for the 2006 growing season. The methodology used to fulfill these objectives is described in the following chapters.

## **1.5 Scope**

It is important to note that the implementation of a GIS and the requisite data collection are subject to various economic and physical constraints and the extent and style of PA implementation should be tailored to the specific geographic context. Also, because crop growth and soil conditions are influenced by numerous variable factors, application of the field methods used in this study is limited to the field and atmospheric conditions encountered during data acquisition. Most importantly, this project is intended to be a practical exercise in establishing a spatial management system for a company and integrating already existing data, as well as gathering field data specific to the context of the company and their land holdings. The conclusions made in regards to interpolation techniques as well as correlations between measured properties should be validated under a variety of field and atmospheric conditions, and under more controlled experimental settings. Therefore, any extrapolation of the results to other sites and environmental conditions should be carried out with due diligence.

## **1.6 Thesis Organization**

This thesis is organized into five chapters, which provide a background for the current project, describe its objectives and how they were achieved. Chapter 2 provides a global literature review of work that has been carried out in the field of precision agriculture, as well specific studies related to soil salinity and plant chlorophyll determination and related remote sensing methods. Chapter 3 gives a detailed description of the methodology used for field work, as well as the methodology used for subsequent spatial and statistical analysis. Chapter 4 presents the results of the creation of the geographic information system: thematic maps of the Mangote plantation, as well as maps of individual study parcels displaying variations in soil conductivity and crop leaf chlorophyll content, are presented and discussed. Issues related to the spatial interpolation models used to generate the individual parcels maps are also discussed in Chapter 4, and the results of correlations between soil conductivity measurements (EM38), plant chlorophyll measurements (SPAD) and NDVI values derived from satellite imagery are presented and discussed. Chapter 5 provides a summary and conclusions based on the results, as well as providing recommendations for further study.

## **CHAPTER 2 LITERATURE REVIEW**

This chapter reviews the literature relevant to the development and application of Precision agriculture (PA) by looking at the history of its development and scope of adoption. The role of Geographic Information Systems in PA implementation is then described. The following section describes the characterization of soil salinity and moisture, as well as crop nitrogen status, using ‘on-the ground’ field methods and remote sensing. The last section describes how information collected in the field can be spatially interpolated using Geostatistical techniques to create continuous surfaces from discrete data.

### **2.1 Precision Agriculture**

Agriculture, as humankind’s most important life-sustaining activity, has had a tremendous global impact; the extent of agricultural land use and its environmental and social significance are enormous. With global population at over 6 billion, commercial agriculture and its impacts are continuously under expansion and reverberate through all aspects of our biosphere. Not only do agricultural activities, which account for 75% of global freshwater withdrawals, play a central role in global water scarcity issues, they also have repercussions on biodiversity and climate change (FAO 2007). These environmental impacts, along with the continued reality of world hunger, make agricultural productivity and sustainability the key problem of the coming century. In order to solve this problem we must cross the “principle remaining agricultural frontier...land productivity – coaxing more production from each parcel of cropland” (Postel, 1999). More importantly however, we must encourage increased production through the effective use of agricultural inputs; that is, by optimizing agricultural production in order to ensure sustainability.

Traditionally the individual production unit, for example a field that is often hectares in size, is treated uniformly. Agricultural inputs such as fertilizers, herbicides, insecticides, fungicides as well as irrigation water are uniformly applied. However, crops obviously respond to major environmental and soil variables varying on a much finer scale. The discrepancy between the uniformity of crop treatments and the uniqueness of

individual plants' physiological responses implies that a significant portion of the farmers' costs is going to waste. This waste not only represents a financial loss, but also often represents a negative impact on the surrounding environment. Precision agriculture therefore seeks to retain the benefits of large-scale mechanization while accounting for this local in-field variation.

The principle behind PA is simple: The environment is heterogeneous and should be managed accordingly. Ignoring environmental heterogeneity represents a loss in efficiency that we simply cannot afford. In order to accomplish this, we must undertake both descriptive activities in order to *characterize* environmental heterogeneity, and prescriptive activities to *respond* to it. Modern technological advances have made these activities of description and prescription possible with unprecedented sophistication and precision. Geographic Information Systems allow us to catalogue and analyze the vast amounts of information required to operate large-scale farms, by drawing upon and synthesizing information from a variety of sources and capitalizing on their spatial location. Remotely sensed information from earth observation satellites, in conjunction with information collected on the ground, also provides an important source of information for a GIS, and allows us to partake in descriptive activities in ways which greatly surpass traditional methods in ease, time commitment and detail. By using 'on-the-ground' sensors and remote sensing to characterize spatially variable environmental parameters in great detail, and GIS to manage this information and respond to the information, PA has the potential to increase production efficiency and lower production costs, while at the same time promoting environmentally sustainable crop management. These technologies and their use in PA represent "a great leap forward for agricultural production" (Jhoty and Autrey, 1998)

### **2.1.1 History and Scope**

The concept of PA, although present in some form for centuries, was formulated formally in 1986 in a seminal paper written by Fairchild (Fairchild 1994). Since its theoretical inception PA has been explored widely, although it has been applied mainly in Europe and the United States, where farm sizes are large and landowners are willing to make larger capital investments in PA technology (Pederson et al., 2001). Accordingly,

many significant PA developments took place in the US, Canada, Australia and Western Europe in the mid-to-late 1980s (Zhang et al., 2002) with principle areas of PA development taking place in regards to high yield crops such as wheat, barley, corn and soybean. (Jhoty and Autrey, 1998). Regardless, PA management has experienced considerable attention from researchers worldwide and has become a prominent issue in modern agriculture, with PA related experiments reported in recent literature from China, Korea, Indonesia, Bangladesh, Sri Lanka, Turkey, Saudi Arabia, Australia, Brazil, Argentina, Chile, Uruguay, Russia, Italy, The Netherlands, Germany, France, UK, United States and Canada (Zhang et al., 2002). All of these experiments with various aspects of PA practice have occurred in parallel with the development of spatial database management and environmental monitoring tools, and the literature explores a range of issues from general PA implementation guidelines to specific indices for the analysis of crop spectral information (Barnes et al., 1996; Atherton et al., 1999). Excellent reviews are available of its development and myriad aspects from leaders in the PA field (Moran, Inoue et al. 1997; Plant 2001).

In comparison to high yield crops however, PA application to sugarcane is still in its infancy. Regardless, important advancements have occurred in sugarcane PA in countries such as Australia and South Africa, with research groups such as South African Sugarcane Association (SASA) and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) having carried out multiple studies regarding PA and its application to sugarcane cultivation (Blackmer and White 1998; Cook and Bramley 1998; Rossel and McBratney 1998; Schmidt et al., 2001; Gers 2003). Sugarcane PA has also seen significant contribution from Brazil which, with over 6 million hectares of planted cane, harbors the world's largest sugarcane industry (Magalhaes and Cerri 2007). Large scale projects have been initiated to design a sugarcane yield monitor, which remains commercially unavailable at the time of writing, and to map physical and chemical soil attributes, with the aim of furthering the implementation of PA in sugarcane crop in Brazil (Cerri and Magalhaes 2003).

PA for sugarcane has also been explored in Asia, with extensive land and soil cover monitoring made possible by the Indian Remote Sensing Satellite (IRS-1). The most significant contributions have come from India, Japan and Thailand (Chakraborti et

al., 2002; Shanwad et al., 2004; Saravanan et al., 2005; Ueno et al., 2005). A great source of motivation for this sugarcane PA development comes from the fact that the sugar industry relies strongly on agricultural inputs to increase yield and instead of treating specific high-infested or nutrient deficient areas, large areas are often uniformly treated with herbicides and fertilizers (Simoes et al., 2005).

In spite of these myriad developments and widespread interest, some studies suggest that adoption of PA related technologies, such as yield monitoring, is not as widespread as initially forecasted (Zhang et al., 1997; Lowenberg-DeBoer 2003). Although there are many complex sociological and economic reasons for this, most studies reveal that the greatest barrier to PA adoption is the substantial initial capital investment required, and the fact that the most significant benefits of PA usually come after the accumulation of many years of detailed soil and plant variability data. (Blackmore et al., 1994; Pederson et al., 2001; Sevier and Lee 2003; McBratney et al., 2004; Adrian et al., 2005). Unfortunately, this barrier may seem even greater in a developing country context, where profitability in agriculture is often even lower (Cook et al. 2003). Despite this uncertainty, PA has been shown to be profitable in both a developed and developing country context (Stombaugh et al. 2001; Godwin et al., 2002; Bongiovanni and Lowenberg-Deboer 2004) and a survey of economic studies related to PA concludes that the majority of PA management schemes show positive net returns (Lambert and Lowenberg-DeBoer 2000). In general, there is also strong correlation between PA profitability and farm size and even farms of just over 200 ha, can expect profits and an amelioration of product quality by implementing PA (Stombaugh, et al., 2001; Godwin et al., 2002). Although smaller farm sizes and land tenure may be an issue in the global south, the existence of landowners with large landholdings such as Azucarera Nacional in Panama, provides strong cause for PA implementation in the developing country context, where optimization of production is most pressing.

It is important to note that as sustainable development becomes economically valued, the benefits of PA implementation will accordingly become increasingly apparent. That is, when reduced environmental burdens are recognized and evaluated and become part of the ultimate reward, PA will gain increased importance in the agricultural sphere (Auernhammer 2001). Currently very few economic models used to determine the

optimal number of PA management units within a given field, pay express attention to environmental externalities (Ancev et al., 2004). For example, Danish farmers see greater economic benefits in taking action based on knowledge of field heterogeneity, as opposed to simply gathering information, than do producers in the United States and UK; this can be attributed to restrictions on N rates below the economic optimum in Denmark, as well as substantial taxation on the use of pesticides.

Similar environmental laws are being implemented throughout continental Europe to limit N fertilization on arable land, especially to protect drinking water areas.(Link et al., 2006) . European Union legislation has accordingly prompted certain local governments to pass laws which further reduce the loss of N to groundwater from agricultural sources, greatly motivating management systems which encourage the efficient use of N input. Furthermore, a case-study of variable-rate application of nitrogen on an Argentinean farm, which shows how profitability can be maintained while reducing the application of nitrogen, demonstrates how PA works for both environment and development goals (Bongiovanni and Lowenberg-Deboer 2004). Using a wide range of hypothetical government restrictions on N application levels, a sensitivity analysis shows that precision agriculture is a modestly more profitable alternative to traditional whole field management (Bongiovanni and Lowenberg-Deboer 2004). These results imply that appropriate environmental policy reforms by local governments worldwide will be pivotal in encouraging the use of precision farming and that such management schemes encourage economic *and* environmental optimization.

## **2.2 Geographic Information Systems**

Geographic Information Systems (GIS) are a cutting-edge technology that allows the unprecedented manipulation and analysis of geographic information. In practical terms, a GIS simply consists of computer software, hardware and data, and personnel to help manipulate, analyze and present information that is tied to spatial location. A GIS can provide farm managers an effective method to visualize, manipulate, analyze and display spatial data, providing the backbone of a PA system.

There are two principal ways to input and visualize data in a GIS:

1) **Raster data:** consists of information in a grid, composed of pixels, where each pixel represents a location and has a certain value. Data obtained from remote sensing, such as satellite imagery and aerial photography are in this format. Discrete point data obtained from field sampling can also be interpolated to create continuous raster coverages of the sampled properties (Crosier et al., 1999).

2) **Vector data:** consists of linear, rather than grid, information and is composed of points, lines and polygons. Geographic features such as buildings, bodies of water and boundaries of fields and agricultural management units etc. are in vector format. One can attach attributes such as size, type and length, among other properties to vector data (Crosier et al., 1999).

The information that can be integrated into a GIS is many and varied, contributing to the flexibility and adaptability of GIS to many applications. In general these information sources consist of digitized and scanned maps, tables of attribute data, spatial data gathered using a GPS device, as well as data gathered using remote sensing devices such as satellites. What makes GIS a crucial part of PA systems is that they ultimately involve a high level of data integration between positioning and sensing technologies and control systems (Earl et al., 2000). GIS is therefore able to provide the necessary platform for complex information flows, which include spatial and temporal components, and to facilitate the use of expert knowledge already held by farmers, to synthesize information into a scheme for optimal crop management (ESRI, 2007). Once digital maps are created of agricultural holdings and linked to relevant attribute information, query and analysis are the key functions of a GIS system used for decision support. Strengthening the system with continued input of field data, a GIS can be used for site-specific management involving the mapping of yield variability and the identification of limiting factors by combined analysis of soil, nutrients, slope and weather information along with field data and remotely sensed data. Visual displays of how properties are changing over a field are extremely useful for farm managers to manage inputs using management zones (Plant, 2001).

Creating a GIS is the first step in PA implementation (Jhoty and Autrey, 1998) and it is becoming a commonplace information technology tool for agricultural production applications (ESRI, 2007). GIS has been applied to sugarcane PA in



particular, for the spatial analysis of soils, and to catalogue land use, weather and slope in order to derive areas suitable for new cane planting (Saravanan et al., 2005). Several studies using GIS for mapping in agriculture have been produced in Thailand (Sah et al., 1995). Sah (2000) focused on developing a methodology to classify the salt-affected soils using remote sensing and GIS. They found that ground truth combined with remotely sensed data was effective in classifying the extremely and moderately saline areas and that the integration of GIS was found effective in classifying low and potentially saline areas. The authors concluded that the integration of GIS with digital image processing was very effective for classifying and monitoring saline soils (Sukchan and Yamamoto 2000).

Saravan et. al (2005) also recognized the importance of building farm information systems for the Thai sugar industry. A mapping project was initiated in order to map cane fields and other land uses using the Indian Remote Sensing (IRS) - 1D satellite, as well as to build a farm record system with links to the map and finally to analyze this information using GIS software (Saravanan et al., 2005). The study concluded that GIS was a powerful tool that allowed for interpretation, analysis and decision making for sustainable and profitable farming. The maps generated and field data gathered for this study were used for monitoring cane area, delivering inputs and planning for locating new potential areas for planting. Japanese efforts to implement sustainable sugarcane production also relied on the integration of RS with GIS; these tools were used to evaluate cane growth conditions and prepare field maps and resulted in improved management practices on individual farms (Ueno et al., 2005)

GIS is not only an important tool to input and analyze crop management information, it can also be used in conjunction with GPS and variable rate technology (VRT) to directly control agricultural inputs once information is gathered. Small-scale variations in site-quality can be detected using GIS and related PA technology and this information can then be translated into valid crop management guidelines (Jarfe and Werner. 2000). German researchers initiated a field-based project where management guidelines were designed and then transformed into software modules to allow farmers to adjust cropping measures to respective management zones in a field (Jarfe and Werner, 2000) . They were able to successfully apply a decision support system based on

ArcView using if-then rules, for calculating site specific and agronomic optimal sowing rates. Many similar projects have been realized using GIS in conjunction with variable rate controllers for site specific application of fertilizer (Seidl et al., 2001 ; Miller et al., 2005 ), herbicides (Al-Gaadi and Ayers 1999) and irrigation water (Perry et al., 2002)

In light of these studies, it was decided to build a farm level GIS for the Azucarera Nacional sugarcane plantation using the Environmental Systems Research Institute (ESRI) ArcGIS 9.0 software. The GIS was established to optimally manage the vast amounts of production data with a spatial component, used at the plantation. The GIS will also provide a basis for site-specific input management at the plantation through the use of soil and plant health maps generated from detailed sampling on the individual parcels that make up each farm. The priorities for detailed sampling were identified according to the most pressing needs for crop management at the plantation and the limited resources available at the site. Soil conductivity monitoring was carried out because salinity was the most pressing challenge for soil management at the plantation. For plant chlorophyll assessment the SPAD meter was used for whole-field crop monitoring to manage nitrogen applications. Spatial interpolation was used to create continuous coverage maps from this data. Finally, remote sensing was explored as a qualitative tool for assessing crop health. Literature relevant to these topics is reviewed in the following sections.

### **2.3 Determination of soil and plant properties in precision agriculture**

Traditionally, the determination of soil and plant properties over a field has been limited to direct methods of analysis such as gravimetric and chemical analysis of soil samples taken with an auger or foliar analysis in a laboratory to determine plant health characteristics. These methods, although direct, are extremely labor, time and cost intensive, and therefore field sampling is often carried out at a coarse resolution. These limitations have prompted the development of ground-based and remote sensing methods that can be used to determine relevant soil and plant properties with much greater ease and at a much higher spatial resolution.

### **2.3.1 Soil salinity assessment**

In dry areas soil salinity is a frequent consequence of irrigation, and soil salinity has significant implications for crop health. In fact, early detection of saline areas can be used to enact preventive measures before a crop is significantly damaged (Jackson 1986). It has been shown that in high-salinity conditions with high vapor pressure deficits which is common in irrigated areas, plant stress exists, limiting the plant from achieving optimal growth (Howell et al., 1984).

In order to account for the adverse effects of soil salinity and soil moisture deficits, bulk soil electrical conductivity (EC) can serve as an indirect indicator of important soil physical properties. The traditional method of obtaining soil salinity by determining the conductance of the soil solution extract is too labor, time, and cost intensive to be practical for field-scale applications (Rhoades et al., 1999). Apparent soil electrical conductivity, which can easily be measured using an EC sensor, can serve as surrogate measure for salinity, clay content, clay mineralogy, soil pore size and distribution, soil moisture content and temperature (Rhoades et al., 1999).

In order to determine apparent soil electrical conductivity (EC), two basic designs of EC sensors are now commercially available. One is an electrode-based sensor requiring soil contact, and the other is a non-invasive electromagnetic induction (EM) sensor. The EM38-DD (dual-dipole), the most popular of such sensors, is a conductance meter which allows collection of on-the-go simultaneous collection of GPS referenced horizontal and vertical EM38 signal data (Barnes et al., 1996). Electromagnetic induction methods are most appropriate for the determination of soil salinity in precision agriculture applications because the volume of measurement is larger than traditional point soil sampling for chemical analysis, and it is much less labor, cost and time intensive (Rhoades et al., 1999). The EM has therefore become the first choice for measuring soil salinity in a geospatial context for the following reasons (Corwin and Lesch 2003):

- (i) Measurements can be taken as quickly as one can move from one location to the next.
- (ii) The reading represents the mean of a large volume of soil and hence reduces problems with point sampling.

(iii) Measurements in relatively dry or stony soils are possible because no contact is necessary between the soil and the EM sensor.

In areas of salt-affected soils, most of the EC signal is related to concentration of soluble salts. However, in non-saline soils, EC variations are primarily a function of soil texture, organic matter, moisture content and cation exchange capacity (Rhoades et al., 1999). Several studies have shown that bulk soil electrical conductivity serves as an effective proxy for soil texture and soil salinity (Rhoades et al., 1989). Soil physical properties such as soil texture have a direct effect on water-holding capacity, cation-exchange capacity, crop yield, production capability and nitrogen loss variations within a field (Lund et al., 2001). Furthermore, case studies of site-specific N applications based on EC maps that have proven to be effective (Lund et al., 2001).

Fortunately, multiple measurements of soil EC have been shown to correspond when taken at the same time of the year (Sudduth et al., 2001). This implies that soil EC patterns stay relatively constant and that detailed soil EC maps created from systematic measurements can be used in multiple years. It is important to note however that soil moisture and temperature differences across measurements dates can have a significant effect on EC measurements, and this should ideally be taken into account when creating soil EC coverages (Sudduth et al., 2005). EC values mapped across fields sometimes show weak temporal associations due precisely to variation in soil moisture contents, which depends on climatic conditions and irrigation schedule (McCutcheon et al., 2006).

One study evaluates field-scale apparent electrical conductivity mapping for delineating soil properties correlated with productivity and ecological properties (Johnson et al. 2001). After EC mapping 250 ha of contiguous farmland, using a geo-referenced soil-sampling scheme separating each field into four EC classes that were sampled in triplicate (0- to 7.5 and 7.5-30-cm depth), soil physical and chemical parameters were characterized for each of the classes. Physical parameters investigated included bulk density, moisture content and percentage clay and chemical properties studied were organic matter, total C and N, extractable P, laboratory-measured electrical conductivity and pH. Investigated properties showed significant differences among EC classes ( $P < 0.06$ ) at one or both depths. Positive correlation was found between bulk density, percentage clay, EC and pH and negative correlation was found for all other soil

parameters. Potential uses of this study include assessing temporal impacts of soil condition management and site-specific soil nutrient management (Johnson et al., 2001).

Similarly, Sudduth (2005) related EC data to measured soil properties across a wide range of soil types, management practices and climatic conditions (Sudduth, Kitchen et al. 2005). They found that correlations of EC with clay content and cation exchange capacity (CEC) were generally highest and persistent across all fields. Other soil properties (soil moisture, silt, sand, organic C) were strongly related to EC in some study fields but not in others.

A study carried out in Turkey used GIS and remote sensing to estimate the effect of salinity on crop yield (Cullu 2003). GIS media was used to combine and analyze an EC map created from soil sampling, land use maps, a soil map and results showed that increasing EC values up to 14.4 dS/m caused decreases in cotton and wheat of respectively. In general, increases in salinity above the threshold for cotton and wheat resulted in a linear decrease in crop yield (Cullu 2003).

Monitoring plant water availability is an important step in optimizing irrigation systems to maximize yield and this is directly affected by the salinity level of the soil (Neumann 1997). As soil moisture content, not only soluble salts, has an effect on the measured soil conductivity, it is necessary to take soil conductivity measurements under uniform soil moisture conditions (ideally at field capacity) in order to isolate the effects of soil salinity on soil conductivity measurements (Sudduth et al., 2001). As it is not always possible to take conductivity measurements under uniform moisture condition, soil moisture or volumetric soil water content (VWC) can also be monitored in conjunction with soil conductivity using a variety of commercially available instruments as well as basic gravimetric techniques. As a method for assessing field VWC, Time domain reflectometry (TDR) is widely recognized as the best electronic method available (Chandler et al., 2004).

Based on the above, it was decided to use the Geonics EM-38 sensor to conduct soil conductivity surveys for the purposes of this project. Soil moisture measurements were also taken using the FieldScout TDR 300 soil moisture meter.

### **2.3.2 Plant chlorophyll estimation**

Plants are subject to a wide variety of biotic and abiotic limits to growth such as disease, adverse climatic conditions and most commonly a deficit of water or nutrients (Jackson 1986). Plant ‘stress’ can be defined as any such limit that adversely influences growth, and whose limitation results in higher plant yield (Jackson, 1986). A goal for good agricultural production then becomes the early detection of plant stress in order to minimize the adverse effects of stress on plant growth. This must be balanced by the fact that over application of nitrogen fertilizer for crop production has important environmental consequences, most significantly on water quality, and hence the use of N fertilizer should also be mitigated (Ahmad et al., 1999).

Nitrogen (N) is an essential nutrient for plant growth and is most frequently the limiting nutrient in agricultural soils. Consequently, nitrogen is the most commonly applied nutrient in agricultural systems and its economic and environmental management is of paramount importance to farmers and regulators. A uniform application of Nitrogen (N) to varying soils results in a wide range of N availability to the crop. Nitrogen applied in excess of the crop usage results in waste of the grower’s input expense and a potential negative effect on the environment. Conversely, inadequate N levels represent a lost opportunity for crop yield and profit (Lund et al., 2001).

Traditional methods of assessing spatial variability of N over large fields, such as tissue analysis and soil testing are both labor and cost intensive and require many point samples. The need to develop sensors which identify areas of a field requiring specific inputs in specific quantities has led to the development of the handheld chlorophyll meter, introduced by the Minolta Corporation, known as the SPAD 502. The fact that handheld chlorophyll absorbance meters are quick, non-destructive and can be used in the field have made them a popular tool in crop nitrogen assessment (Richardson et al., 2002).

One major limitation of the chlorophyll meter in determining crop nitrogen status is that the readings are affected by many factors including varietal differences, growth stages, nutrient deficiencies other than N, environmental conditions and measurement positions on leaves (Wu et al., 2007). Furthermore, chlorophyll meter readings are generally taken at a limited number of locations in the field and therefore these results

often provide little information concerning the nitrogen status across the entire field (Han et al., 2002). As such, chlorophyll meters, by themselves, are not considered practical tools to characterize crop nitrogen status on a whole-field basis (Han et al., 2002). Regardless, in light of the fact that taking chlorophyll meter readings presents a significant time, cost and labor advantage over foliar analysis on a field scale, it was decided for the purposes of this study to assess the SPAD 502 meter as field mapping tool for N.

#### **2.3.2.1 Remote sensing in plant chlorophyll estimation**

The power of remote sensing as an important tool for the improvement of world agricultural production has been recognized for over almost three decades (Buffalano and Kochanowski 1979). Remote sensing provides a primary source of input data for GIS and many PA applications. Remote sensing applications explored in the literature include pre-growth soil fertility and moisture analyses, crop growth monitoring and yield forecasting (Brisco et al., 1998).

Fortunately, due to the close correlation between leaf chlorophyll and leaf N concentration, remote sensing provides a ‘one-shot’ opportunity to evaluate N variability over large fields (Daughtry et al., 2000). Numerous studies have investigated the correlation between spectral response and leaf chlorophyll concentration and have concluded that spectral responses in the visible and NIR wavelengths, and vegetation indices calculated from the spectral values, are a measure of the amount of photosynthetically active tissue in plant canopies (Wiegand et al., 1996). Blackburn (1999) found that reflectance of narrow wavebands with the visible region was moderately related to chlorophyll concentrations, while ratio indices, employing wavebands in the near infrared and visible region were more successful. Also, one of the first studies on the spectral response of sugarcane to nutrient and water deficiencies found that infrared/red ratios measured over plots with adequate nitrogen, potassium and water were significantly higher than those with nutrient deficiencies (Jackson et al., 1981). Another important finding of this study was that although irradiance values varied considerably depending on cloud cover, the changes in infrared/red ratio were minimal,

indicating that the ratio could be adequately measured for sugarcane irrespective of cloud cover variance (Jackson, 1986).

Multispectral reflectance data can be used to compute a variety of indices that are well correlated to plant biophysical parameters related to photosynthetic activity and plant productivity (Jackson 1986; Pinter and Moran 1994; Wiegand, Anderson et al. 1996; Blackburn 1999). One of the most commonly used spectral indices for the analysis of crop parameters using remote sensing is the Normalized Difference Vegetation Index (NDVI), developed almost 30 years ago by a NASA scientist (Tucker 1979). Tucker (1979) found in his seminal paper that the IR-red difference divided by the sum was or the *normalized* vegetation index, was sensitive to the amount of photosynthetically active vegetation. Since its conception, NDVI has become a well established method of assessing plant health and is calculated as follows:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

The NDVI, which varies between -1 and +1, quantifies the relative difference between the near infrared reflectance ‘peak’ and the red reflectance ‘trough’ in the spectral signature; the NDVI value for highly vegetated targets will be close to unity and non-vegetated targets will be close to zero, with negative values rarely occurring for natural targets (Lamb 2000). Calculating the NDVI and reducing the multiple waveband data at each image pixel to a single numerical value (index) is a way to produce images that give an excellent visual indication of plant stress by highlighting changes in vegetation health, or more specifically plant nitrogen status (Lamb, 2000).

It is important to note that the straightforward use of NDVI for detection of various crop canopies has some important limitations due to its sensitivity to soil background and atmospheric effects; background reflectance as well as Leaf Area Index (LAI) have been found to confound the detection of relatively subtle differences in canopy reflectance caused by changes in leaf chlorophyll concentration (Daughtry, Walthall et al. 2000). Several indices, such as the Soil Adjusted Vegetation Index (SAVI) (Huete, 1988) and the Modified Soil Adjusted Vegetation Index (MSAVI) (Wu et al., 2007) have been developed to account for the impact of soil brightness, however these effects are less relevant for crops with dense canopies such as sugarcane (Noble and



Crowe, 2001). The current project makes use of a high resolution Quickbird satellite image to create NDVI coverages of the fields under study. These images are used for both visual interpretation of plant health, and their relationship with coverages derived from SPAD chlorophyll meter sampling is also briefly examined.

## **2.4 Spatial Analysis**

Spatial variability of soil physical and chemical properties is a result of various superimposed processes acting at different spatial scales and over time periods, including soil and crop management practices as well as naturally occurring structure and texture of soil (Castrignano et al., 2000). In order to characterize and predict this variability spatial prediction or interpolation is used. Spatial prediction is a wide-ranging subject and has many obvious applications in GIS and remote sensing: GIS programs integrate methods of spatial interpolation, in order to allow the creation of coverages, once point data has been collected in the field.

Statistical tools such autocorrelation function; semivariograms and state-space have all been used to evaluate the structure of spatial distributions of soil properties; unlike ‘classical statistics’ that presuppose the independence among observations and disregard their location intra-field, they take advantage of the spatial dependence of observations and make use of the location of each observation to predict the values of unsampled locations (Dourado-Neto et al., 1999). The Geostatistical analyst extension of ArcGIS provides various deterministic and stochastic Geostatistical methods for the creation of continuous surfaces from discrete data. Two of the most well-established and commonly used spatial interpolation methods, Inverse Distance Weighting and Kriging, are described below (Johnston et al., 2001).

Inverse Distance Weighting (IDW) is a deterministic interpolation method. Deterministic methods are used to create a surface from measured points based on the extent of similarity and forces the resulting surface to pass through the data values, a method which is known as exact interpolation (Johnston et al., 2001). IDW implements the basic assumption of Geostatistics that points located close to one another are more similar than points located farther apart; in order to predict the value of a point at an unmeasured location, IDW uses the measured values of the points around the prediction location

(Johnston et al., 2001). As the name implies, IDW assumes that the influence of measured points diminishes with distance and hence gives closer points greater weight in the final prediction than points located farther away. A drawback of IDW however is that there is no way to characterize the error in the model and no a priori method of estimating the optimal exponent or the number of the closest neighbor (Kravchenko and Bullock 1999).

Kriging is a commonly applied statistical method employed by soil scientists used to estimate values of soil properties at unsampled sites (Castrignano et al., 2000). It is a method of interpolation based on regionalized variable theory and depends on expressing spatial variation of the property in terms of the variogram, while minimizing prediction errors that are themselves estimated (Oliver and Webster 1990). Similar to IDW, it relies on a weighting scheme where sample locations closer to the sample have a greater impact than those farther out, and has found extensive applications in soil science (Gotway et al., 1996; Bishop and McBratney 2001).

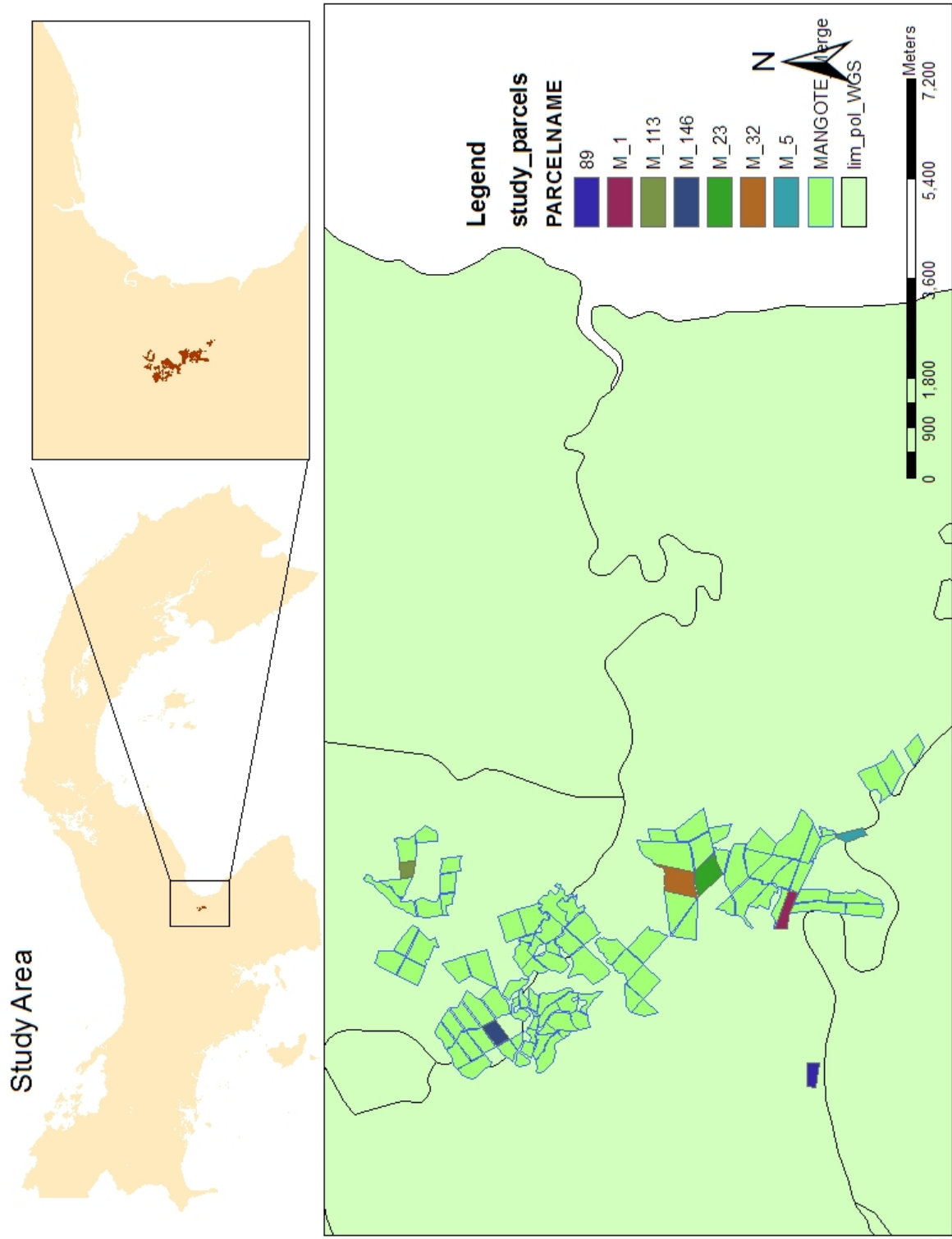
Robinson and Metternicht (2006) compared the accuracy of Ordinary Kriging, IDW and splines for interpolating soil properties including pH, electrical conductivity and organic matter; they found that overall all of the methods gave similar root mean square error (RMSE) values. Geostatistical tools were also used by Douaik (2005) to identify the spatio-temporal variability of soil salinity using both field and laboratory measurements and found that Kriging produced reliable estimates of soil salinity at unobserved spatial locations (Douaik et al., 2005). The current study compares IDW and Ordinary Kriging as methods to create interpolated surfaces from discrete field data.

## CHAPTER 3 METHODOLOGY

### 3.1 Study area

The study area is located in the heavily-deforested Azuero peninsula region of Panama where most land is dedicated to cropping and cattle ranching. The area spans the provinces of Coclé and Herrera in an area of the peninsula known as the “arco seco” (dry arc). The land holdings of Azucarera Nacional span over 15,000 hectares of primarily agricultural land, devoted to sugarcane cultivation with a small area covered with primary and secondary forest. The agricultural area, located closest to the township of El Roble, in the district of Aguadulce, is divided into five plantations: Santa Rosa, Mangote, San Jose, Los Canelos and Panela.

For the purposes of this study, digital map creation and the detailed field sampling and links to production information used to create a database, were limited to the Mangote plantation centered at approximately 80°35'W, 8°10'N. This plantation was chosen because of the wide range of soil chemical and physical conditions. Also, some parcels show persistent soil salinity problems, due to proximity to the Pacific Ocean. Parcel boundary mapping and database creation for the purpose of establishing a GIS platform focused on the entire Mangote plantation. Detailed sampling of soil and plant properties however, was focused on seven of the over 150 individual parcels that make up the Mangote plantation. The study area is shown in Figure 3.1.



## 3.2 Field Methods

### 3.2.1 Sampling methodology

On the Mangote plantation of Azucarera Nacional,, seven study sites (parcels of land) were chosen for detailed sampling, where data was obtained over the course of two years. The seven study parcels were chosen according to a variety of factors, including availability of aerial photos of the parcel, occurrence of mechanical harvesting on each parcel to account for the possibility of future yield monitoring, and representative soil classes (see Table 3.1). The parcels varied in size from 7 to 25 hectares. In most cases, due to the size of the parcels, field data collection for a single parcel would take several days. Field data was collected at 5 different times during 2005 and 2006, spanning both the wet and dry seasons as well as several stages of cane maturation, from the early growth to pre-harvest.

Table 3.1 Soil classes of study parcels

|                   | Soil Class                   |
|-------------------|------------------------------|
| <b>Parcel 1</b>   | highly fertile               |
| <b>Parcel 5</b>   | highly fertile               |
| <b>Parcel 23</b>  | persistent salinity problems |
| <b>Parcel 32</b>  | persistent salinity problems |
| <b>Parcel 89</b>  | highly fertile               |
| <b>Parcel 113</b> | persistent salinity problems |
| <b>Parcel 146</b> | average                      |

The first two field collection runs (hereafter referred to as EM38 I and EM38 II) were used to collect ‘data bundles’ consisting of; soil samples and soil conductivity readings with the Geonics Limited EM-38 soil conductivity meter. The remaining three data bundle collection runs (hereafter referred to as Field Data Run (FDR) 1, 2 and 3 respectively) were used to collect soil conductivity readings with the EM38, plant chlorophyll readings with a hand-held Minolta SPAD 502 chlorophyll meter and soil moisture readings using a Spectrum Technologies Field Scout TDR 300. All field data

was spatially referenced using a hand-held Trimble GPS unit. The name and area of each study parcel, as well as the start dates of each data bundle are listed below in Table 3.

1. The first two field collection runs were limited to soil sampling and soil conductivity readings because only the soil conductivity meter was available at that time. The remaining three data bundle collection runs were carried out upon acquisition of the remaining sampling equipment.

Table 3.2: Field data collection locations, dates and type of data bundle collected.

|                   | Area (Ha) | Soil Samples | EM38 I    | EM38 II   | FDR1      | FDR2      | FDR3      |
|-------------------|-----------|--------------|-----------|-----------|-----------|-----------|-----------|
| <b>Parcel 1</b>   | 11.52     | 05-Jul-05    | 05-Jul-05 | 19-Jul-05 | 14-Oct-05 | 13-Feb-06 | 24-May-06 |
| <b>Parcel 5</b>   | 7.95      | 17-Jun-05    | 17-Jun-05 | 13-Jul-05 | 04-Oct-05 | 19-Jan-06 | 11-May-06 |
| <b>Parcel 23</b>  | 20.66     | 13-Jun-05    | 13-Jun-05 | 08-Jul-05 | 06-Dec-05 | 25-Jan-06 | 02-May-06 |
| <b>Parcel 32</b>  | 25.32     | 28-Jul-05    | 28-Jul-05 | 12-Aug-05 | 24-Oct-05 | 04-Mar-06 | 31-May-06 |
| <b>Parcel 89</b>  | 8.1       | 23-Jun-05    | 23-Jun-05 | 17-Jul-05 | 25-Nov-05 | 08-Feb-06 | 15-May-06 |
| <b>Parcel 113</b> | 7.2       | 27-Jun-05    | 27-Jun-05 | 15-Jul-05 | 14-Nov-05 | 01-Dec-05 | NA        |
| <b>Parcel146</b>  | 11.2      | 20-Jul-05    | 20-Jul-05 | 17-Aug-05 | 21-Nov-05 | 06-Mar-06 | 16-May-06 |

It is common in Panama for a parcel to be divided into *decimos*, which is approximately equal a tenth of a hectare, or  $\sim 1000 \text{ m}^2$ . The exact dimensions of a decimo are dictated by the overall shape of the parcel and the dimensions of the spacing between ‘surcos’ (irrigation furrows) that run between the rows of cane, and hence *decimo* dimensions may slightly vary, but in general are  $\sim 30\text{m} \times 30\text{m}$ . The decimo divisions were the most convenient markers to use for navigation within the fields and hence were used to guide the sampling density.

A soil sample was taken once, roughly in the centre of each decimo. Spad, TDR, EM38 instrument readings were taken all together at three locations per decimo: at the

first or second row (~2.5 m from the edge of the decimo), in the middle of the *decimo* and at the edge of the next *decimo*, or approximately, on average, every 10 m. The position along the row was approximated near the centre of the decimo, so that samples were taken on a ore or less evenly spaced grid. At each sampling location a reading was taken with a handheld GPS device, and the coordinates recorded were given at least 10 minutes to stabilize. Readings from each instrument were recorded by hand in a field notebook and subsequently entered into a spreadsheet. Figure 3.3 shown below gives a schematic of the sampling locations within the boundaries of a decimo.

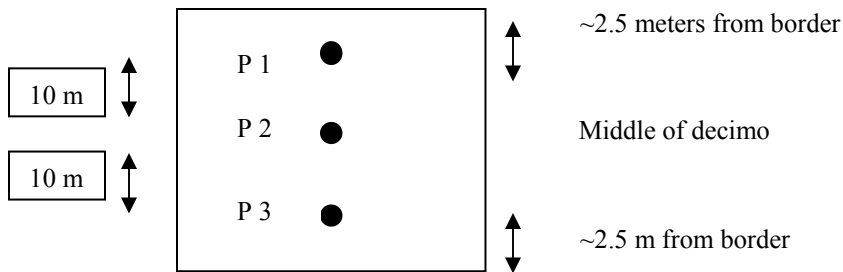


Figure 3.2: Sampling locations within decimo boundary.

The following sections provide more detail in regards to the theory and sampling procedures related to the specific plant and soil properties sampled.(Konica\_Minolta 2003)

### 3.2.2 Soil conductivity determination

Soil conductivity measurements were taken using the Geonics Limited EM-38 soil conductivity meter. The instrument works by inducing circular eddy-current loops in the soil, whereby the magnitude of the loops is directly proportional to the EC of the soil in the vicinity of that loop. The current loops generate secondary electromagnetic fields that are proportional to the value of the current flowing within the loops. The secondary induced electromagnetic field from each loop is then intercepted by the receiver coil of the instrument, forming the output voltage which is proportional to the apparent electrical conductivity (Corwin and Lesch 2003). This is a result of the fact that the properties of the secondary field differ from the primary field because of soil properties such as clay content, water content and salinity (Corwin and Lesch 2003). In order to obtain conductivity measurements, the instrument was calibrated at the beginning of every field

measurement run in the morning at the same location following the manufacturer's procedure and a reading was taken at that location at the end of each field run in order to check for instrument drift. Measurements were taken in both the horizontal and vertical dipole modes which provide an indication of the ground conductivity to a depth of 0.75m and 1.5m respectively, as indicated by the manufacturer's manual. Readings were recorded at the highest point at the sample site (at the top of the furrow rather than between planted rows) in order to avoid 3D electrical field profile of surrounding soil and great care was taken to avoid electrical interference from any nearby metal objects (Sharma and Gupta 2000).

### **3.2.3 Plant chlorophyll determination**

Leaf health measurements were obtained using a SPAD 502 chlorophyll meter, an instrument that measures leaf chlorophyll content, which is correlated to the amount of nitrogen content of the plant (Konica\_Minolta, 2003). The values measured by the meter correspond to the amount of chlorophyll present in the plant leaf which is calculated based on the amount of light transmitted by the leaf in two wavelength bands between which the absorbance of chlorophyll is different. The SPAD meter uses the red area, where absorbance is high and unaffected by carotene, and the infrared area, where absorbance is extremely low, as the basis of its measurements (Konica\_Minolta, 2003). The SPAD 502 has a  $0.06\text{cm}^2$  measurement area and calculates an index in 'SPAD units' based on absorbance at 650 and 940nm, with a claimed accuracy of  $\pm 1.0$  SPAD unit (Richardson et al., 2002). In the immediate area of the soil sample site, three leaves at breast height were chosen for sampling. Three recordings, spaced 10 cm apart where taken on each leaf (see Fig 3.3). The arithmetic mean of the nine recordings was then used for all subsequent analyses (Peterson et al., 1993).



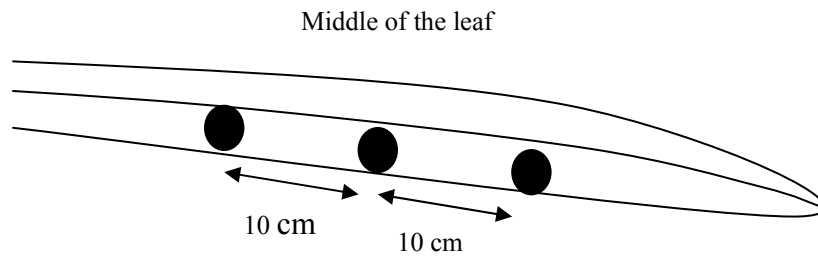


Figure 3.3: Sampling locations on a leaf

### 3.2.4 Soil moisture determination

Soil moisture readings were taken using a Field Scout<sup>TM</sup> TDR 300 soil moisture meter obtained from Spectrum Technologies Inc. The instrument takes volumetric soil moisture readings based on time domain reflectometry. The volumetric water content of the soil is the ratio of the volume of water in a given volume of soil to the total volume of soil. The saturation value therefore depends on the total pore space of the soil, which is equal to the percent volumetric water content when soil saturation is reached. Because the dielectric permittivity ( $\epsilon$ ) of soil minerals is considerably lower than that of water (typically  $3-5\epsilon$  as opposed to  $80\epsilon$ ) the bulk permittivity of the soil is governed mostly by the soil moisture content. The Field Scout uses this property to determine the in situ volumetric soil moisture content (Spectrum\_Technologies, 2000). It is accepted that the relationship between apparent dielectric permittivity and volumetric water content is independent of soil type, density, temperature and soluble salts content (Nadler et al., 1999). Although it is recognized that salinity affects TDR functionality in measuring volumetric soil moisture by increasing the attenuation of the TDR signal and hence reducing its accuracy, reports in the literature are conflicting as to whether this leads to over or under estimation of the measured parameter and at field capacity, salinity is shown to have no detectable effect on the readings (Nadler et al., 1999).

The instrument consists of a shaft mounted probe with two attached rods that act as wave-guides. A wave is sent down the rods and after traveling their length, is partially reflected at the interface between the tips of the rods and the soil. The received signal is transformed into a square wave output with a frequency proportional to the volumetric water content. The volume range that is being measured by the instrument is an elliptical

cylinder extending, radially, 3 cm from the rods with a length equal to the length of the rods (Spectrum\_Technologies, 2000). The instrument, equipped with 20cm rods was fully inserted into the soil at three locations spaced approximately 20 cm apart at the soil sampling site and volumetric soil moisture readings were recorded and the arithmetic mean of these three readings was used for all subsequent analysis.

Soil moisture measurements were also obtained by traditional gravimetric methods when it was not possible to obtain TDR soil moisture probe readings. This was necessary for FDR 2 and 3 due to the fact that the TDR instrument was damaged. All soil gravimetric analysis was carried out in the Azucarera Nacional soil and plant analysis laboratory using standard methods (Gardner, 1986).

### **3.2.5 Soil sampling**

Soil samples were collected using a spiral auger inserted to a depth of 60 cm. Soil removed from the auger was placed in a plastic bag containing a tag identifying the parcel number, decimo number and geographic coordinate taken with the GPS device. Each sample was mixed for uniformity and sealed in a plastic bag. Soil sampling resolution for chemical analysis was lower than the sampling resolution used for other crop and soil properties due to the labour and cost involved in soil sample collection and analysis. All soil chemical analyses were carried out at the Instituto de Investigacion Agropecuaria de Panama (IDIAP) laboratory. Samples were analyzed using standard methods, for soil organic content, moisture, electrical conductivity of saturated paste extract, bulk density as well as mineral composition. All soil texture analysis was carried out using the standard Boyoucou hydrometer method (Sheldrick and Wang, 1993).

## **3.3 Spatial analysis and statistical methods**

### **3.3.1 Digital map creation**

As the first step for creating a crop information database and for the purposes of carrying out subsequent GIS analysis, a digital map was created of the Mangote plantation. As the only available hardcopy maps of the land holdings were those created by traditional cartographic methods in 1977 and considerable changes in parcel boundaries had occurred since that time, aerial imagery, obtained from aerial surveys

conducted in 2002, was acquired and used in order to more accurately demarcate parcel borders on each farm. Digital orthophotographs (planimetrically corrected aerial photographs) were chosen based on the fact that analytical photogrammetry is used on such photos to remove relief and camera angle tilt displacement, thus ensuring maximum accuracy of boundary lines. Forty-two such aerial orthophotographs were acquired from Tommy Guardia cartographic institute, located in Panama city, Panama.

The orthorectified aerial images were imported into ESRI's ArcGIS 9.0 as images (\*.tiff) and referenced under the NAD 27 projection system and then re-projected into WGS 1984 using the geographic transformation utility of ArcGIS 9.0 found in ArcToolbox. Using these high-resolution photographs, and the historical hard-copy maps to identify features and parcel numbers, parcel boundaries were traced using a mouse and each stored as a vector file. These final 'shapefiles' were then merged using the "Data Management" tool "Join" operation of ArcToolbox.

Each parcel of land, representing the operational production units of the plantation, was assigned a unique identifier in the attribute data table associated with the shapefile encompassing all the parcels of Mangote plantation. The identifiers were used to link the parcel map with the plantation's production information, contained in the Oracle database used to store and manage Azucarera Nacional's production information. This database management innovation was implemented at the company in 2004. Creating the link between the shapefile containing the parcel boundaries and the production information was undertaken in two ways:

- 1) Using ArcCatalogue a spatial database connection was created with the geographic data stored in the relational database system of the plantation's Oracle database. The link created a real-time spatially referenced information system where the digital maps created in ArcINFO had access to the plantations's historical production records. This was created for the purposes of future onsite GIS analysis

- 2) The Oracle database information was also extracted as .dbf files and was then linked directly to the digital map of Mangote. These files were used for the analysis purposes of the current dissertation project.

### **3.3.2 Spatial analysis**

Ground-based data is typically composed of discrete points that generally require spatial data analysis to be interpolated to a continuous grid. These continuous data layers are often revealing of the spatial patterns of heterogeneity in soil and plant health conditions, and hence can be very useful to farmers as management tools (ESRI 2007). Creating such continuous data layers (hereafter referred to as “coverages”) of important soil and plant properties, for use in input management, is the major goal at this stage of PA implementation. Using the Geostatistical Analyst and Spatial Analyst extensions of ArcINFO 9.2, it was possible to create these coverages from the discrete field data collected.

#### **3.3.2.1 Creating XY shapefiles**

Creating XY shapefiles, based on the field data gathered, is the first stage in creating continuous raster coverages in ArcGIS. Once the raw field data was transcribed into spreadsheets and saved as database files (.dbf) (which is the format accessible to ArcCatalogue) the data was thoroughly reviewed visually and via sort functions for obvious value outliers and outliers due to transcription errors. This was an extremely labor intensive process considering the size and number of datasets to be reviewed (hundreds of individual data points for the 40 datasets listed in Table 3.1). Once the datasets were reviewed, they were mapped in ArcCatalogue and XY shapefiles were created using the ‘Create Feature Class from XY Table’ command in ArcCatalogue.

Shapefiles were displayed in ArcMap and projected to the WGS 1984 coordinate system. These shapefiles were then reexamined for both spatial and value outliers, as once this step was completed it became possible to view the spatial distribution of the data. In order to process spatial outliers, coordinates were examined for expected position in the sequence of points (based on the fact that decimos within parcels were sampled sequentially) and when the transcription error was not obvious, simple interpolation was used to place point samples in the expected position. Decisions regarding global value outliers were based on judgment and field experience. This stage of data processing is very important when creating coverages from point data because outliers can have dramatic effects on the final output surface.

### **3.3.2.2 Creating Geostatistical analyst layers**

There are several interpolation methods available in ArcGIS to create continuous raster coverages from discrete data. Among the various methods available, IDW and two methods of applying Ordinary Kriging were chosen and compared based on their ease of use and relative accuracy. The interpolation methods examined are described below.

#### **A) Inverse distance weighting (IDW)**

The Geostatistical Analyst extension of ESRI's ArcInfo 9.1 was used to create all interpolated surfaces. Using IDW, it is possible to specify the level of significance that surrounding known points have on the interpolated values. A higher power places more emphasis on the nearest points leading to a more detailed surface (less smooth) whereas decreasing the power gives more influence to points farther away (ESRI 2006). Therefore, in order to create a coverage using this method, one must specify the power used to calculate interpolated values.

Test surfaces were created using both the first power, which has shown promise in soil surface interpolation applications (Robinson and Metternicht 2006), the second power which is the most commonly used power and provided as the default value setting, as well as the "Optimize Power" option provided by Geostatistical Analyst, which finds the power that results in the lowest RMSE. The associated RMSE values for surfaces created were then examined and in light of the fact that resulting differences in RMSE were very small and all surfaces created were visually very similar, a power of '2' was chosen to create all subsequent surfaces. This option was chosen over the auto RMSE minimizing approach so that the method was consistent among surfaces created with IDW, in order to achieve a better comparison with other methods. The IDW method also requires that the user input the number of neighbors considered in the interpolation. Similar trial and error examination led to the use of the default value setting of '15', which means that up to 15 of the nearest data points are considered when calculating the interpolated value (the number of points may be less than 15 depending on the geometry of the situation and the search radius).

#### **B) Ordinary Kriging**

Unlike IDW which is a deterministic interpolation method based directly on the surrounding measured values, Ordinary Kriging (OK) is a geostatistical interpolation

method, which is based on a statistical model that includes autocorrelation, or the statistical relationship between the measured points. Kriging is most appropriate when it is known that there is a spatially correlated distance or directional bias in the data, and therefore it is commonly used in soil science (ESRI 2006). Although this provides the user creating the surface with more information regarding the measure of uncertainty or accuracy regarding the prediction, which is not possible with deterministic interpolators such as IDW, it also requires estimation of more input parameters. Creating coverages using OK is therefore a much more involved process than IDW and requires thorough exploration of the data.

Unfortunately, there is no a priori method of determining what parameters will produce the best prediction surface and the chosen model and input parameters varies according to the characteristics of each particular data set, and often achieving the best model by adjusting the semivariogram characteristics is a process of trial and error. For the purposes of this project, the principle goal was to keep the creation of the coverages as ‘user-friendly’ and straightforward as possible in order to make the creation of soil maps as accessible as possible to the largest number of users, regardless of training. In order to accomplish this, two sets of coverages were created using OK interpolation. The first set involved the least amount of input from the user as possible and the second set involved the estimation of parameters based on the particular dataset. The two methods of coverage creation using OK are described below:

- 1) Coverages were created using all of the default values provided in the Ordinary Kriging module of Geostatistical Analyst. All data distributions were assumed to be normal and no transformations were applied to the initial datasets and no trend removal occurred. The partial sill, nugget, lag size and number of lags were all left unchanged from the default values provided for the dataset by Geostatistical analyst. Coverages using this method are hereby referred to as “OK” coverages.

- 2) Coverages were also created by considering results of a more detailed exploration of the source data, which involved removing spatial trends and applying systematic transformations to the raw data values. Using the “Explore Data” tool available through the Geostatistical Analyst menu, the following sequence of steps was followed for each coverage:

- i) The histogram of the data was examined to check for normality. When the data was skewed, a lognormal transformation was attempted. If the lognormal transformation pushed the data distribution towards normality it was applied and if it had either no effect on the distribution, it was not applied.
- ii) Spatial trends in the data were then examined using the “Trend Analysis” tool of Geostatistical Analyst. The trend analysis tool creates a three-dimensional surface of the study area, projecting the sampled points to the height attribute value. This surface is then projected onto planes that are perpendicular to the map plane, and a polynomial is fit to each projection (ESRI 2006). If there was an observable trend (the projection was not a straight line with zero slope), a first order trend was removed from the data (the lowest order of trend removal is recommended). (ArcGIS manual)
- iii) When necessary, the lag distance was adjusted so that the lag distance multiplied by the number of lags was equal to less than half the largest distance between points in the set.

This process was carried out to create coverages for the “Horizontal” attribute of the EM38 I and EM38 II datasets. Coverages using this method are hereby referred to as “OKTR” coverages. The parameters used to create the OKTR coverages are given below in Table 3.3.

Table 3.3 Parameters used in creating OKTR coverages

|      |            | Parcel and date | Transformation | Trend removal | Lag distance (m) |
|------|------------|-----------------|----------------|---------------|------------------|
| EM38 | Horizontal | 1_jul19         | NA             | first         | NA               |
|      |            | 1_july5         | NA             | first         | 35               |
|      |            | 5_july13        | log            | first         | NA               |
|      |            | 5_june17        | log            | first         | NA               |
|      |            | 23_july8        | log            | first         | 37               |
|      |            | 23_june13       | log            | first         | NA               |
|      |            | 32_july28       | NA             | first         | 39               |
|      |            | 32_aug12        | log            | NA            | 39               |
|      |            | 89_july17       | log            | first         | 23               |
|      |            | 89_june23       | log            | first         | 23               |
|      |            | 113_jul15       | NA             | first         | 18               |
|      |            | 113_jun13       | NA             | first         | 18               |
|      |            | 146_aug17       | log            | first         | NA               |
|      |            | 146_july20      | NA             | first         | NA               |

### 3.3.3 Satellite image analysis

#### 3.3.1 Satellite image selection and processing

A high resolution satellite image was obtained from the Quickbird satellite. The Quickbird Bundle Standard Orthoready Geotiff DVD format was chosen among available products, with 8K tiling and a 60 cm spatial resolution for the panchromatic image and a 2.44m resolution for the, multispectral image. Standard imagery is radiometrically corrected, sensor corrected and mapped to a cartographic projection (WGS84 UTM). The orthoready format was chosen so that ground control points could be applied for georectification. Ground control points (GCPs) were taken in the field at the corners of each study parcel as well as at easily identifiable points near the edge of the image capture region.

The “Georeferencing” module of IDRISI Andes software was used to georeference the original image using ground control points; the resulting spectral response of the adjusted image varied considerably in the NDVI values produced from the raw image, due to the “rubber sheeting” process used to georectify the image.



“Rubber sheeting” causes the satellite image pixels to be recalculated, thus no longer providing a true representation of the spectral response. Upon examination of the georectified satellite image in comparison to the raw image, it was decided to accept the original image with basic georectification; this, in order to save accuracy of the spectral response. Regardless, overlaying of the original satellite image with the digital boundaries of parcels created using aerial photography, showed excellent visual agreement. Discrepancies between the spatial accuracy of the original satellite image when overlaid with the digitized parcel boundaries were on the order of less than 1m and hence no additional georectification was deemed acceptable.

### **3.3.3.2 NDVI**

Spectral analysis of the remotely sensed imagery obtained from the Quickbird satellite was carried out in the IDRISI Andes Edition software. In order to create NDVI coverages from the raw multispectral bands provided, the “Raster Calculator” module of IDRISI was used. The software calculates the value for each pixel of a new raster using the algebraic combination of the red (Band 3) and near infrared (Band 4) which corresponds to the formula for NDVI (see Chapter 2) which was input into the raster calculator. In order to create NDVI coverage maps of individual parcels, the following sequence of steps was followed for each study parcel:

- 1) Import ArcGIS parcel outline vector file into IDRISI.
- 2) Create an initial raster which takes the dimensions of the vector file to create a blank image (Blank image is a binary raster that has a pixel value of ‘1’ for all pixels located within the borders of the parcel and a pixel value of ‘0’ for all pixels outside the border).
- 3) Multiply the raster coverage created for the whole scene by the initial raster for the parcel
- 4) Re-digitize the borders of the individual parcels’ coverages, cutting just within the borders of the parcels (one to two pixel widths) to remove any bare soil and edge effects.

### 3.3.4 Statistical comparisons

In addition to the surfaces created using Geostatistical methods, the relationship between individual soil and plant properties collected in the field were also compared using traditional statistical methods. The correlation between different properties was examined by plotting variables in excel and using simple linear regression to find the best fit line. The degree of correlation was reported as the coefficient of determination ( $R^2$ ), the square of the commonly used Pearson's product-moment correlation coefficient ( $R$ ) which gives an estimate of the colinearity between the observed and model simulated values (Legates and McCabe 1999).

In order to undertake comparisons between data collected on the field with spectral data in the form of NDVI values for each pixel, two approaches were undertaken. The first approach exploited the fact that once the discrete data collected on the ground was interpolated to raster form, with a resolution similar to that of the remotely sensed images (where the spectral response is averaged over an area in a pixel) the surfaces could be compared pixel by pixel (Pinter, Hatfield et al. 2003).

In order to do this the first step was to obtain a regression data set for NDVI values. ASCII files were therefore generated containing the NDVI reflectance value for each individual pixel of the raster coverage in IDRSI. Files were exported from IDRISI format into ASCII format and saved in .csv format, after which they were manipulated with a text editor in order to generate a continuous data field. Raster coverages created in ArcGIS of SPAD values for example were similarly converted into ASCII format. These two data sets were then used as the two variables in the simple regression function of 'R' statistical software, available as open access user software. Unfortunately, this approach generated extremely large datasets and led to processing difficulties and hence an alternative approach had to be explored.

Rather than using all interpolated values for regression purposes NDVI values corresponding to the coordinates at which the field data was collected was extracted in ArcGIS using the "Extract by Point" command under the General menu of ArcToolbox. The NDVI values, calculated by interpolating the value of the pixels immediately surrounding the specified point, were appended as a new field to the attribute data table for each individual dataset. Rather than using the interpolated values derived in

Geostatistical Analyst, the data points collected in the field were then compared to these NDVI values.

The EM38 horizontal dipole orientation readings (hereby referred to as EM38 horizontal) were chosen for regression comparison with SPAD and NDVI readings because it was expected that if there was to be a correlation to be found between such parameters it would occur more strongly with shallow conductivity rather than deeper soil profile vertical conductivity readings.

## **CHAPTER 4 RESULTS AND DISCUSSION**

### **4.1 Annotated digital land holdings maps**

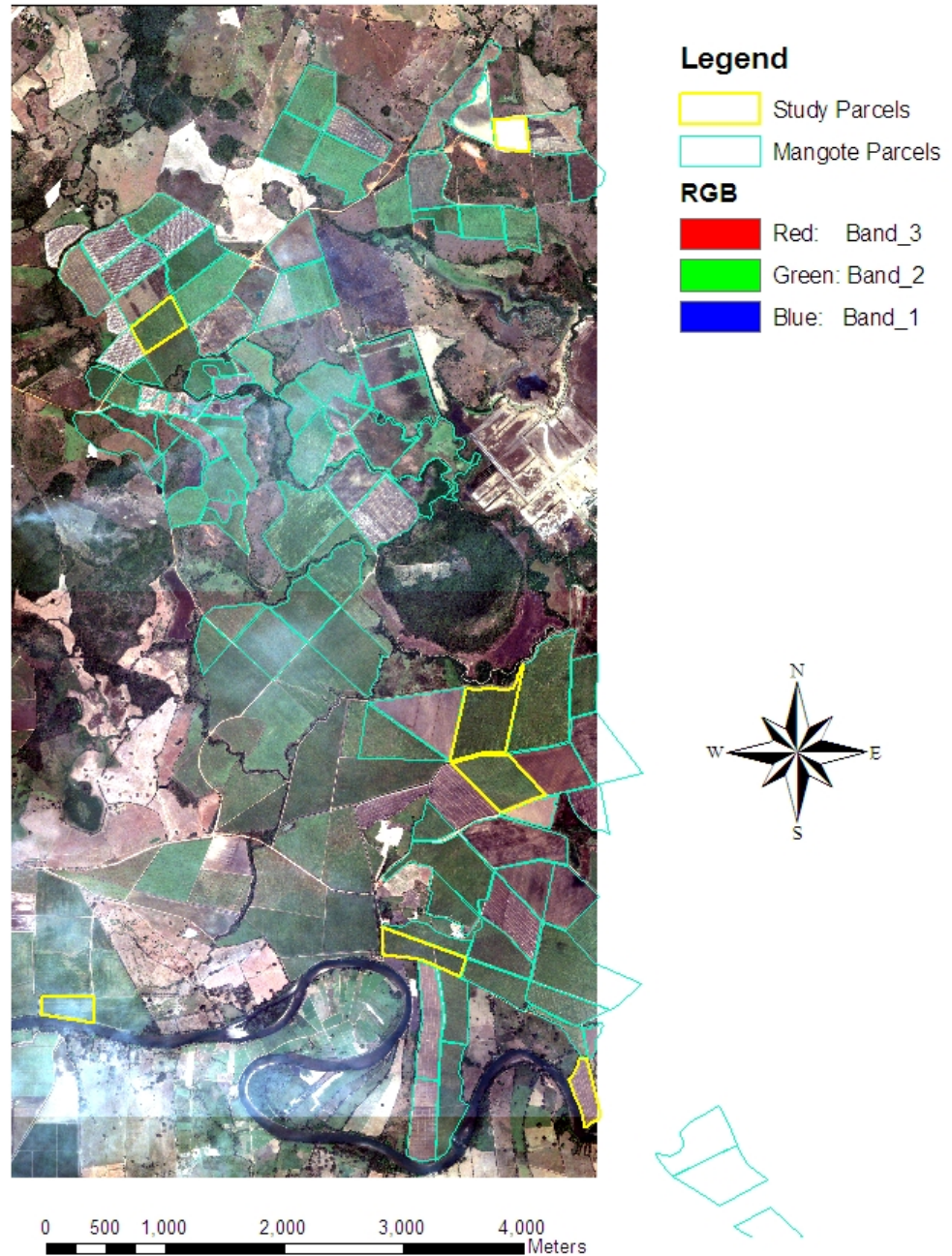
Setting up the Geographic Information System, with an annotated digital land holdings map as its basis, and training users to add information to the system and undertake spatial analysis are the first steps towards sustainable input management implementation (Gonsalves, T. Becker et al. 2005). Up-to-date knowledge of exact parcel boundaries and the ability to view important crop characteristics on a parcel by parcel basis is the first necessary step towards the directed management of inputs at Azucarera Nacional. In light of the fact that the company's land holding span such a large area and are also comprised of units belonging to smaller private landowners known as Colonos, having a visual, interactive platform containing all information relevant to the condition of each parcel would be most helpful for centralized resource management.

The digital map created of Mangote plantation is comprised of various data layers. As part of the project, ArcGIS was installed on one central computer in the main office where the team devoted to cartography and field investigations was put in charge of managing the GIS. Operators were given basic training in GIS principles and shown how to add data, in order to create maps and undertake analysis. Furthermore an important component of the project was to train staff at the company in data collection methods, in addition to basic software skills. This ensures that proper and complete field data collection is continued and further crop and soil information is added to the system.

Figure 4.1 shows a map file (.mxd) created of Mangote plantation with a true color composite of the Quickbird satellite image as its first layer, overlain by the parcel boundaries digitized from the aerial photographs. The satellite image provides striking detail of the terrain and important geographic features of the plantation are clearly visible; the river running through the southernmost portion of the image is the water body from which irrigation water is pumped in the dry season, and the area-under-cane is clearly distinguishable from those areas devoted to other land uses, such as shrimp farming (the white blocks of land visible at the center-east edge of the image).

Figure 4.1: True color composite with parcel polygons

Derived from QuickBird Satellite Imagery Bands: 1,2,3



The attribute data table for the Mangote maps is shown as a screen capture of the ArcGIS software in Figure 4.2. Data concerning the type of soil, the variety of planted cane, the date the cane was planted, as well as numbers related to the expected and actual harvest are all provided in the table. Similar attribute tables have also been linked to the map for the 2004 and 2005 harvest seasons; 2004 being the first year that the Oracle database was put in place and the plantation shifted from paper to electronic record keeping. The hope is to continue to input historical records into the system, as the accumulation of data provides the opportunity for increasingly sophisticated and informative analysis. Additional data layers which will be including in the system in the coming year include digital elevations models (DEMs) of each parcel, as well as an infestation record for each parcel, which is in the process of being included in the Oracle database.

Figure 4.2: Attribute Table, Mangote Harvest 2006

| ParcelName | ParcelCode | OID | FarmCode | Code | Year | Variety | Seed | Soil Type | Area | Row Length | Planting date | Rows |
|------------|------------|-----|----------|------|------|---------|------|-----------|------|------------|---------------|------|
| M_10       | 10         | 9   | 7        | 40   | 2006 | 1       | 3    | A1        | 11   | 53         | 08/03/200     | 0    |
| M_102      | 102        | 73  | 7        | 102  | 2006 | 33      | 3    | B3        | 13   | 53         | 05/04/200     | 1616 |
| M_103      | 103        | 74  | 7        | 103  | 2006 | 9       | 3    | B2        | 5    | 57         | 30/07/200     | 609  |
| M_104      | 104        | 75  | 7        | 104  | 2006 | 33      | 3    | B2        | 9    | 57         | 28/04/200     | 1025 |
| M_105      | 105        | 76  | 7        | 105  | 2006 | 45      | 3    | B2        | 8    | 57         | 06/08/200     | 931  |
| M_108      | 108        | 77  | 7        | 108  | 2006 | 1       | 3    | B3        | 8    | 29         | 01/06/200     | 1950 |
| M_11       | 11         | 10  | 7        | 11   | 2006 | 9       | 2    | A3        | 13   | 57         | 31/01/200     | 0    |
| M_110      | 110        | 78  | 7        | 110  | 2006 | 33      | 3    | B3        | 13   | 29         | 05/06/200     | 3024 |
| M_113      | 113        | 108 | 7        | 113  | 2006 | 30      | 3    | B3        | 5    | 29         | 29/03/199     | 1112 |
| M_115      | 115        | 80  | 7        | 115  | 2006 | 1       | 3    | B3        | 9    | 57         | 08/04/200     | 1084 |
| M_116      | 116        | 81  | 7        | 116  | 2006 | 1       | 3    | B2        | 18   | 29         | 27/08/200     | 4110 |
| M_116      | 116        | 81  | 7        | 116  | 2006 | 1       | 3    | B2        | 18   | 29         | 27/08/200     | 4110 |
| M_118      | 118        | 82  | 7        | 118  | 2006 | 22      | 3    | B3        | 10   | 29         | 12/07/200     | 2379 |
| M_119      | 119        | 83  | 7        | 119  | 2006 | 33      | 5    | B4        | 12   | 57         | 19/08/200     | 1392 |
| M_120      | 120        | 84  | 7        | 120  | 2006 | 44      | 3    | B4        | 13   | 29         | 23/05/200     | 3052 |
| M_121      | 121        | 85  | 7        | 121  | 2006 | 33      | 3    | B3        | 16   | 29         | 07/05/200     | 3748 |
| M_127      | 127        | 109 | 7        | 127  | 2006 | 22      | 3    | B2        | 6    | 29         | 13/06/200     | 1514 |
| M_128      | 128        | 86  | 7        | 128  | 2006 | 1       | 3    | B1        | 4    | 53         | 25/04/200     | 553  |
| M_128      | 128        | 86  | 7        | 128  | 2006 | 1       | 3    | B1        | 4    | 53         | 25/04/200     | 553  |
| M_128      | 128        | 86  | 7        | 128  | 2006 | 1       | 3    | B1        | 4    | 53         | 25/04/200     | 553  |
| M_129      | 129        | 87  | 7        | 129  | 2006 | 1       | 3    | B1        | 9    | 53         | 15/04/200     | 1100 |
| M_130      | 130        | 88  | 7        | 130  | 2006 | 30      | 3    | B1        | 5    | 29         | 23/08/199     | 1063 |
| M_131      | 131        | 89  | 7        | 131  | 2006 | 50      | 3    | B1        | 5    | 29         | 30/03/200     | 1075 |
| M_132      | 132        | 90  | 7        | 132  | 2006 | 9       | 3    | A1        | 10   | 29         | 20/03/199     | 2416 |
| M_133      | 133        | 91  | 7        | 133  | 2006 | 9       | 3    | A1        | 14   | 29         | 13/04/199     | 3379 |
| M_135      | 135        | 111 | 7        | 135  | 2006 | 1       | 3    | A1        | 5    | 29         | 05/04/199     | 1169 |
| M_136      | 136        | 92  | 7        | 136  | 2006 | 44      | 3    | A1        | 12   | 29         | 25/03/199     | 2818 |
| M_14       | 14         | 13  | 7        | 14   | 2006 | 9       | 2    | A1        | 22   | 57         | 09/02/200     | 0    |
| M_141      | 141        | 94  | 7        | 141  | 2006 | 9       | 3    | A2        | 12   | 29         | 07/02/199     | 2891 |
| M_143      | 143        | 96  | 7        | 143  | 2006 | 9       | 3    | A2        | 7    | 29         | 02/03/199     | 1607 |
| M_144      | 144        | 97  | 7        | 144  | 2006 | 9       | 3    | A2        | 3    | 29         | 09/02/199     | 788  |
| M_146      | 146        | 99  | 7        | 146  | 2006 | 9       | 2    | A2        | 10   | 57         | 16/03/200     | 0    |
| M_147      | 147        | 100 | 7        | 147  | 2006 | 9       | 3    | A2        | 10   | 29         | 09/03/199     | 2431 |
| M_148      | 148        | 101 | 7        | 148  | 2006 | 9       | 3    | A2        | 11   | 29         | 16/03/199     | 2611 |
| M_149      | 149        | 102 | 7        | 149  | 2006 | 9       | 3    | A2        | 9    | 29         | 12/03/199     | 2215 |
| M_15       | 15         | 14  | 7        | 15   | 2006 | 9       | 3    | A1        | 32   | 57         | 03/04/200     | 0    |
| M_150      | 150        | 103 | 7        | 150  | 2006 | 45      | 3    | A2        | 7    | 29         | 13/03/200     | 1676 |
| M_151      | 151        | 104 | 7        | 151  | 2006 | 9       | 3    | A2        | 9    | 29         | 06/08/200     | 2163 |
| M_152      | 152        | 105 | 7        | 152  | 2006 | 58      | 3    | A2        | 11   | 29         | 04/03/200     | 2577 |
| M_153      | 153        | 106 | 7        | 153  | 2006 | 33      | 3    | A2        | 15   | 29         | 07/03/200     | 3500 |

## 4.2 Thematic maps

Using the information contained in the attribute data tables, which are linked to the digital map of Mangote plantation it is possible to create a variety of thematic maps, highlighting selected attributes of particular parcels. An example of a thematic map that can be created for management purposes is shown in Figure 4.3 which displays the ratoon number (number of years cane has been perennially harvested from original planting) of each parcel on Mangote farm. This is important for farm management because sugarcane yield tends to decrease with an increasing number of ratoons, and depending on the variety of cane, there is a point at which further harvesting becomes unprofitable and the parcel must be re-seeded (Verma 2002). Although it is possible to identify which parcels have been planted the longest directly from hardcopy lists and individual knowledge of parcel performance from farm managers, a visual display of parcels that require reseeded among the hundreds of planted parcels, greatly facilitates the management process. More importantly, the ability to query production values in conjunction with ratoon number allows farm managers to assess whether it is in fact necessary to reseed a particular parcel when expected, or conversely if a parcel is in need of reseeded before the expected timeframe due to prematurely declining productivity.

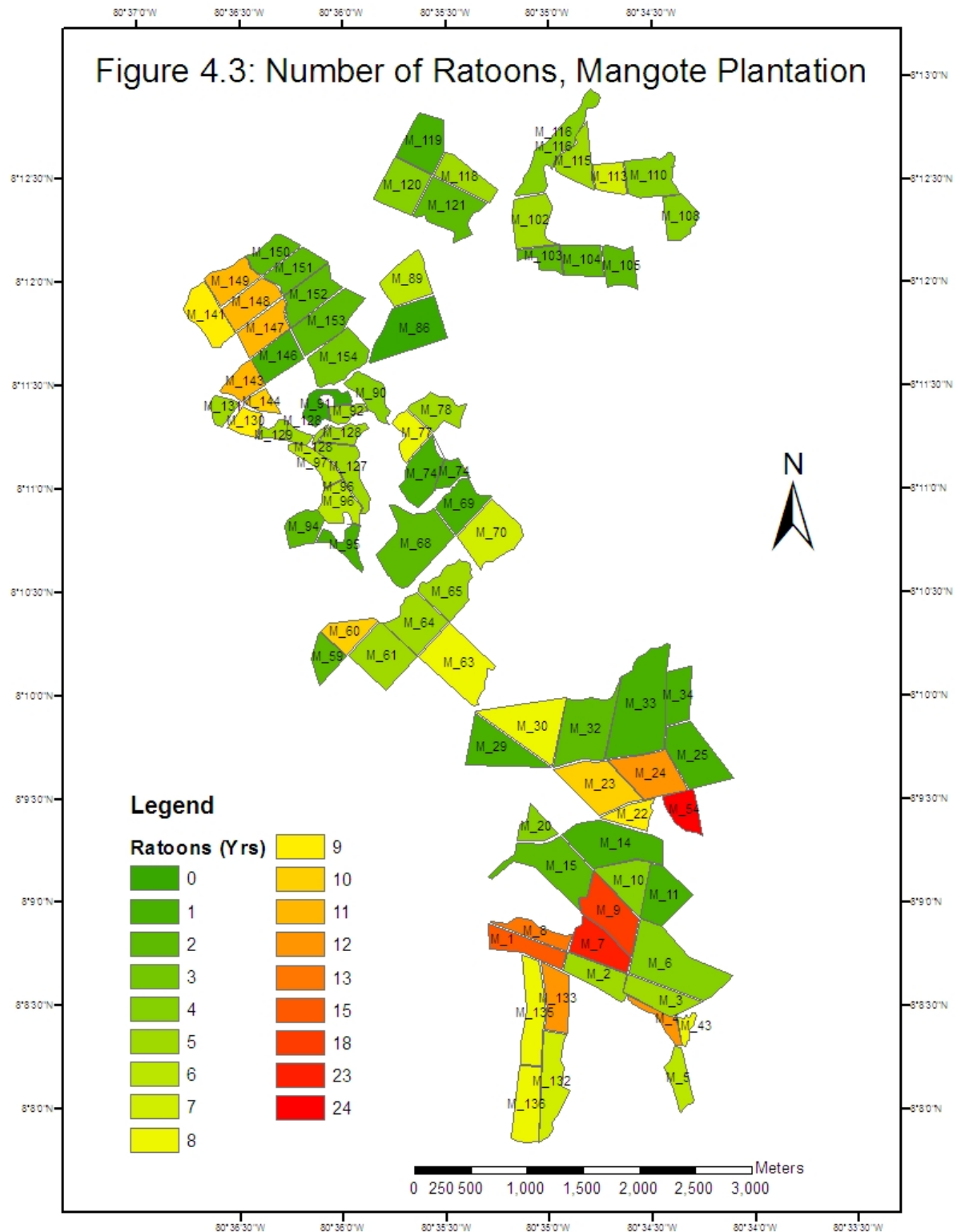
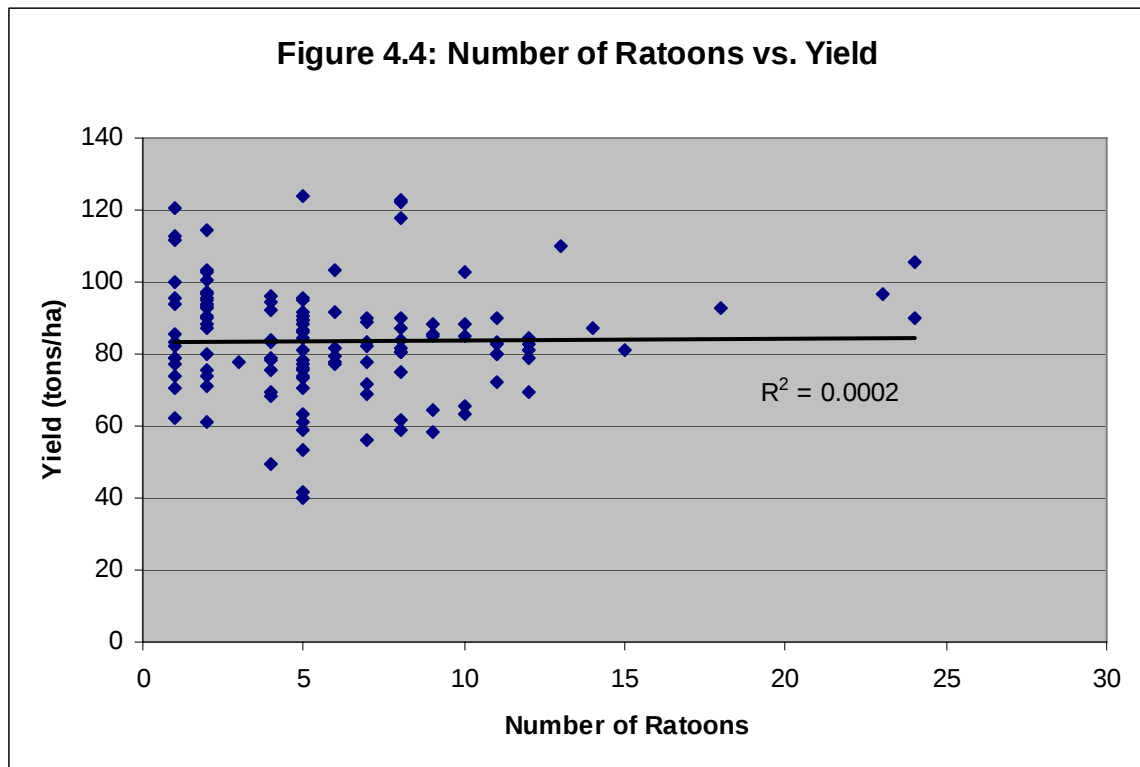




Figure 4.4, based on collected field data, demonstrates that yield decline is far from a linear process and that in practice it is a much more erratic “noisy” process, which concurs with other results found in literature (Simmonds and Walker 1986). Factors that influence the rate of yield decline include the cane variety, soil type and fertility, history of pest and fungal infestations, as well as management practices (Garside 2005). The analytical capabilities of ArcGIS can be used in this instance to isolate such contributing factors, in order to optimize yield.



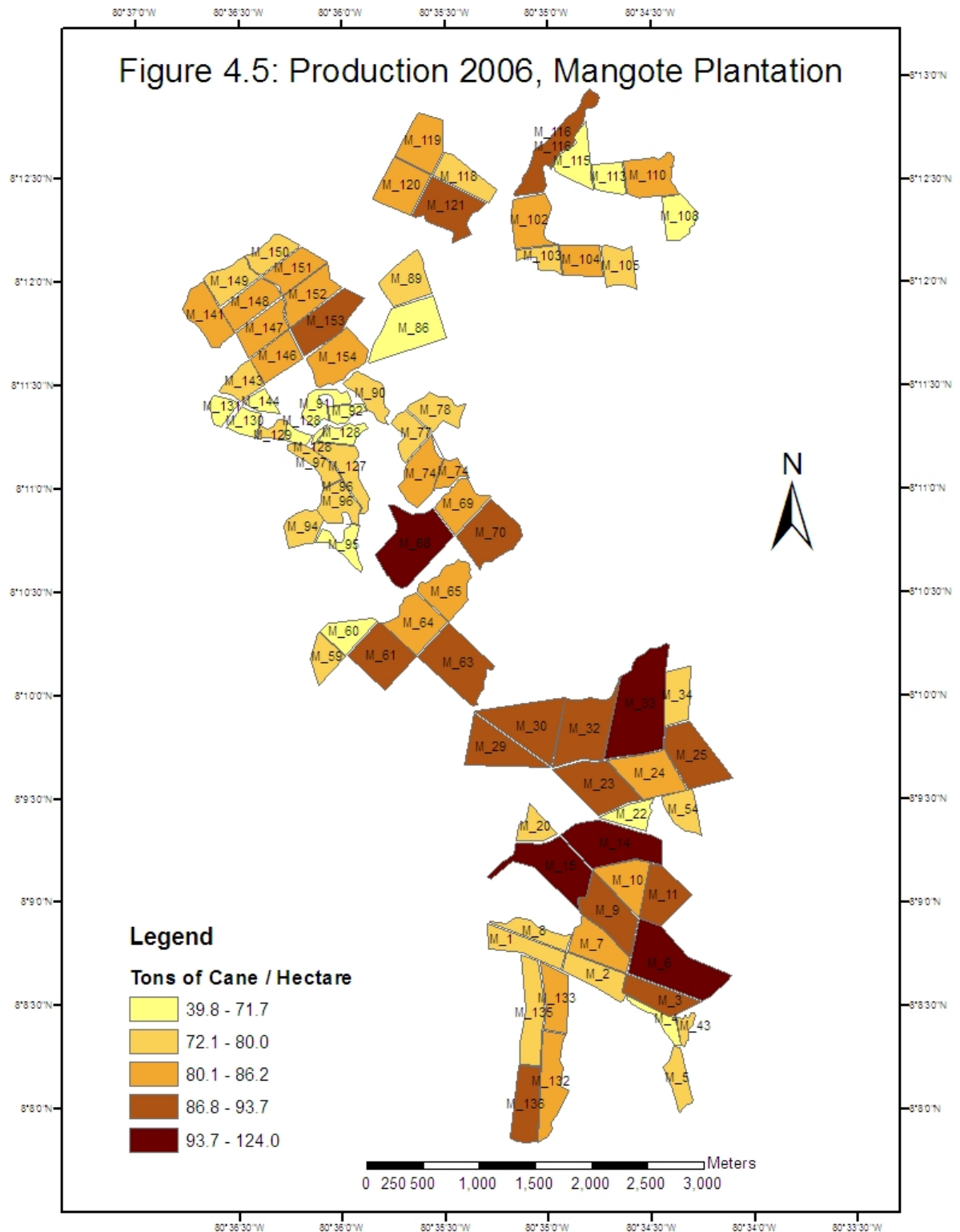
Finally, introducing breaks (fallow periods) and rotations into sugarcane crop production, which is traditionally carried out as a monoculture, has been shown to increase cane yield (Bell, Garside et al. 2001). According to the FAO:

“In their natural state, many soils, in particular in the tropics, cannot be continuously cultivated without undergoing degradation. Such degradation is marked by a decrease in crop yields and a deterioration of soil structure, nutrient status and other physical, chemical and biological attributes. Under traditional low input farming systems, this deterioration is kept in check by alternating some years of cultivation with periods of fallow. The length of the necessary rest period is dependent on inputs applied, soil and climate conditions, and crops. Hence, the

main reason for incorporating fallow into crop rotations is to enhance sustainability of production through maintenance of soil fertility.” (FAO, 2000)

Introducing new crops however is not straightforward and the costs associated with building the expertise and technical capacity to rotate other crops with sugarcane must be balanced against the potential gains in yield and the environmental benefits. ArcGIS can be used to model different break and rotation scenarios, allowing farm managers to explore the practical repercussions of introducing practices that may increase sustainability, while ideally increasing returns.

Finally, Figure 4.5 shows a map of the production of cane harvested from each parcel (standardized by dividing by the area of each parcel) for the 2006 harvest season. The map of production in terms of tons of cane per hectare is perhaps the thematic map of greatest economic importance. This map shows that production of cane varies considerably over the spatial extent of the farm and using this map one is able to identify those parcels where yield values are exceptionally low or high. A GIS user can also use the ‘Query’ function to identify those parcels where the actual production varies considerably from expected production and those parcels which have historically low production values. Furthermore, it is possible to examine the synergistic effects of soil type, cane variety and input parameters in order to identify parcels that require special management attention.



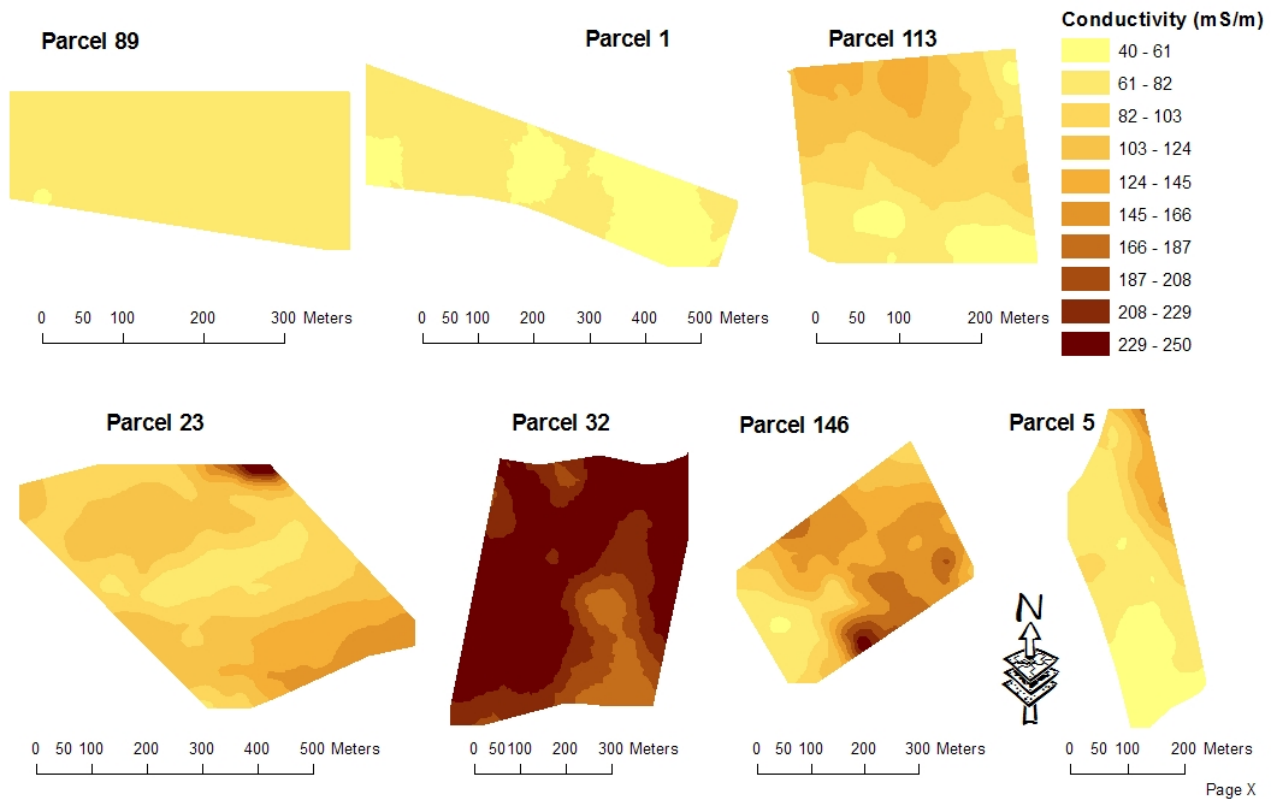
### **4.3 Soil conductivity mapping**

#### **4.3.1 Conductivity zones**

Extensive soil electrical conductivity mapping was undertaken in order to create maps of the soil conductivity profile of individual parcels. As discussed in previous chapters, soil conductivity is a composite measure of various important soil properties, with the greatest contribution coming from soil moisture and soil salinity (Veris 2006). The purpose of conductivity mapping with an EM38 conductivity meter was to assess naturally occurring soil moisture profiles within each study parcel. It was also used to identify salinity zones under consistent soil moisture conditions.

Figure 4.6 shows the soil conductivity profiles of the seven chosen study parcels during the first field data collection campaign (EM38 I – June-July 2005). Conductivity readings taken with the EM 38 device are presented here in the standard units used to express bulk soil conductivity: milliSiemens per meter (mS/m). A Siemen is a measurement of a material's conductivity and expressing the value in mS/m makes the measurement independent of volume (Veris 2006). The coverages have also all been standardized to the same scale, shown in the legend for Figure 4.6. In some parcels, conductivity readings were obtained below and above the limits shown in the legend (40mS/m and 250mS/m respectively). That is, anything above 250 mS/m was cut back to 250 mS/m and values below 40 mS/m were shown as 40 mS/m. The maximum salinity value obtained was 344 mS/m and the minimum value obtained was 11 mS/m. However the legend was designed to give a reasonable indication of the range of conductivity readings obtained, and outlying values beyond the limits shown make up less than 1% of the data obtained.

Figure 4.6: Soil Conductivity, EM38 I Horizontal



Ideally, for salinity measurements, all recordings should be taken in the shortest time period that practical limitations (such as manpower) allow, and soil moisture conditions should be constant among all fields and across dates of samplings. To attain these conditions a common approach is to carry out measurements 24 hours after a rainfall (one sufficient to fill the soil profile); soil at field-capacity. A challenge encountered during practical field conductivity mapping however, is the time required to gather data at the chosen sampling resolution and the inability to arrange manpower to be available 24 hours after such a rainfall. Although soil conductivity sampling with an EM38 offers vast time improvements over the collection and analysis of individual soil samples, rapid and complete soil conductivity assessment is only truly possible with an on-the-go sensor. As most field data collection runs span several days it is impossible to control absolutely for soil moisture conditions, and precipitation events between

sampling times can cause discontinuities in the conductivity profiles obtained. One way to rigorously account for these changes would be to determine the field capacity of the soil belonging to major regions within the parcels in conjunction with logging climatic data from a weather station in order to quantify whether the soil was always at field capacity when readings were taken. In absence of this data, it was deemed adequate to ensure that the field was never far from field capacity by taking recordings as close to the ideal soil moisture condition (field capacity) as possible.

Furthermore, regardless of whether there is an overall increase in conductivity readings with an increased level of soil moisture, the relative values within the field remain constant and localized rainfall differences within a field typically do not cause enough of a difference in the overall soil profile moisture to affect conductivity readings, (Veris 2006). Given that all soil conductivity surveys conducted in the EM38 I field run were done within 24 hours of a precipitation event in the rainy season when the humidity is consistently above 80%, the soil conductivity profiles displayed in Figure 4.6 can be said to provide a good indication of the relative levels of soil salinity found amongst the seven parcels.

From Figure 4.6, it is evident that Parcel 32 has greatly elevated soil salinity in comparison to other parcels and that Parcels 23, 113 and 146 generally show higher soil salinity levels than Parcels 1, 5 and 89. This corresponds to the hands-on knowledge of soil fertility held by farm managers of Mangote; Parcel 1, 5 and 89 are all located at the edge of the river, and are considered to be among the most fertile parcels of the farm, whereas Parcels 23, 32 and 113 were all chosen for persistent salinity problems. According to Table 4.1 which provides a classification of salinity levels based on EM38 readings, parcels 1, 5 and 89 can generally be considered non-saline to slightly saline (with the exception of the north-easternmost portion of Parcel 5). Parcels 23, 32, 113 and 146 however all exhibit areas of moderate to extremely high salinity.

Table 4.1 Salinity classes for plants (DAFWA 2006)

|            | EM38 horizontal (mS/m) |
|------------|------------------------|
| Non-saline | <50                    |
| Slightly   | 50-100                 |
| Moderately | 100-150                |
| Very       | 150-200                |
| Extremely  | >200                   |

Figure 4.6 reveals that in most cases there are definite zones of elevated soil conductivity, which may be due to underlying soil conditions, suggesting the potential benefits to be derived from management zone delineation. The creation of management zones is the second major step in implementing site-specific management, once a descriptive map database has been created. In particular, parcels with elevated salinity levels such as parcels 23, 32, 113, 146 and even parcel 5, which shows a problematic region in its northeast corner, should be subdivided into management zones in which targeted and specific salinity control measures can be implemented. Such measures can include biological or structural controls, depending on the type of saline seep that is occurring and usually consist of appropriate surface water management (Cathcart, 2000).

In making use of this information it is also important to note that the salt tolerance of plants is not only affected by the actual soil salinity but also issues such as waterlogging, soil type, sodicity, depth to water table, salinity of the water table, and rainfall, among other factors (DAFWA 2006). Water and soil management measures that attempt to combat soil salinity should also take these factors into account. Possible salinity control measures include supplying decreased amounts of saline irrigation water to designated parts of the field and undertaking measures to improve surface or subsurface drainage in the required areas (Tanji and Kielen 2002). In the case where variable rate technology is not being used to target fine-scale differences, as is the current situation at Azucarera Nacional, it is easier to implement management methods for larger contiguous areas. Therefore salinity control measures are most easily implemented and necessary for large parcels such as Parcels 23 and 32, both of which span areas over 20

hectares. These parcels can easily be subdivided into regions of common salinity levels, where irrigation and fertilizer management can be adjusted accordingly.

#### **4.3.2 Conductivity changes over time**

When creating management zones for salinity management purposes, it is important to understand how soil conductivity may change in a parcel over time. Identifying zones that stay relatively stable is an important prerequisite for delineating zones for long-term site-specific management of soil.

Figure 4.7, which shows the soil conductivity profiles for Parcel 23, demonstrates that general soil conductivity zones are relatively constant, over the study period. This is an extremely promising result for the creation of management zones. Despite differences in the absolute values of conductivity over the field, from Figure 4.7 it is evident that the regions of elevated and depressed values within the parcel remain relatively constant. The north-east and south-east portions of the Parcel 23 seem to display much higher conductivity values, indicating a concentration of salts. This is also in agreement with the fact the northern portion of Parcel 23 is almost contiguous with Parcel 32 which also shows elevated soil salinity.



Figure 4.7 Conductivity zones at different times, Parcel 23, Mangote plantation

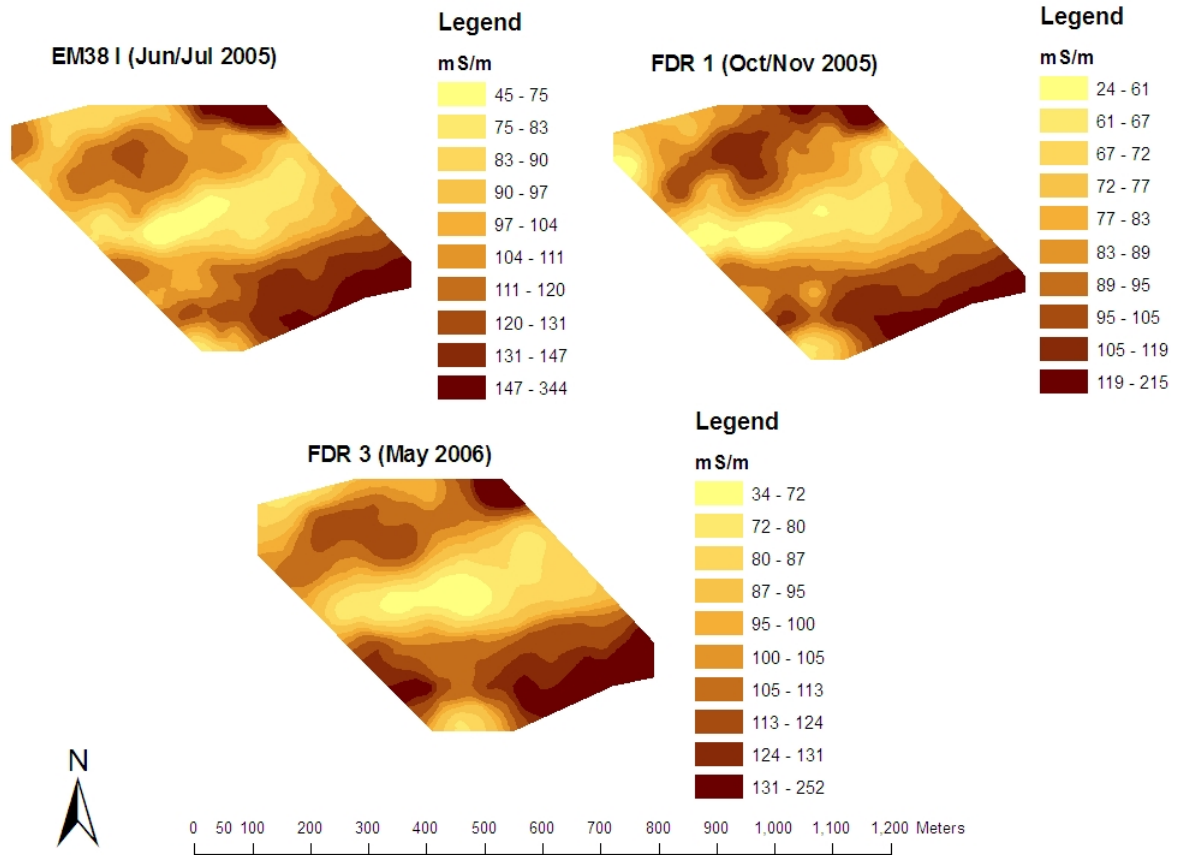
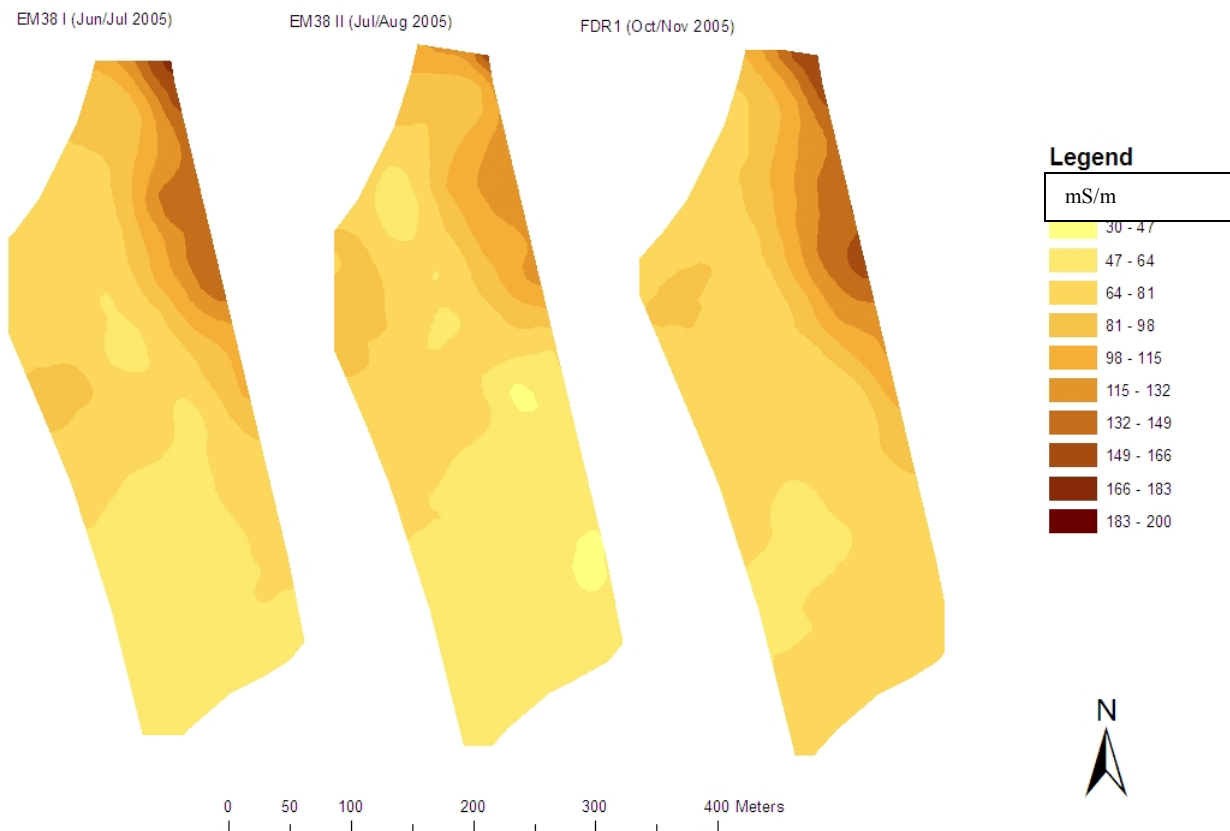


Figure 4.8, which shows how the absolute conductivity of Parcel 5 changes over time, also corroborates these results. As demonstrated by Figure 4.7 it is evident that the areas in which soil conductivity is high remain relatively constant over the field season, however an examination of Figure 4.8 shows that changes in the absolute values of the readings may occur. The principle reasons for these changes in conductivity over time are likely due to soil moisture changes, the leaching of solutes by rainfall or build-up of salinity from irrigation water.

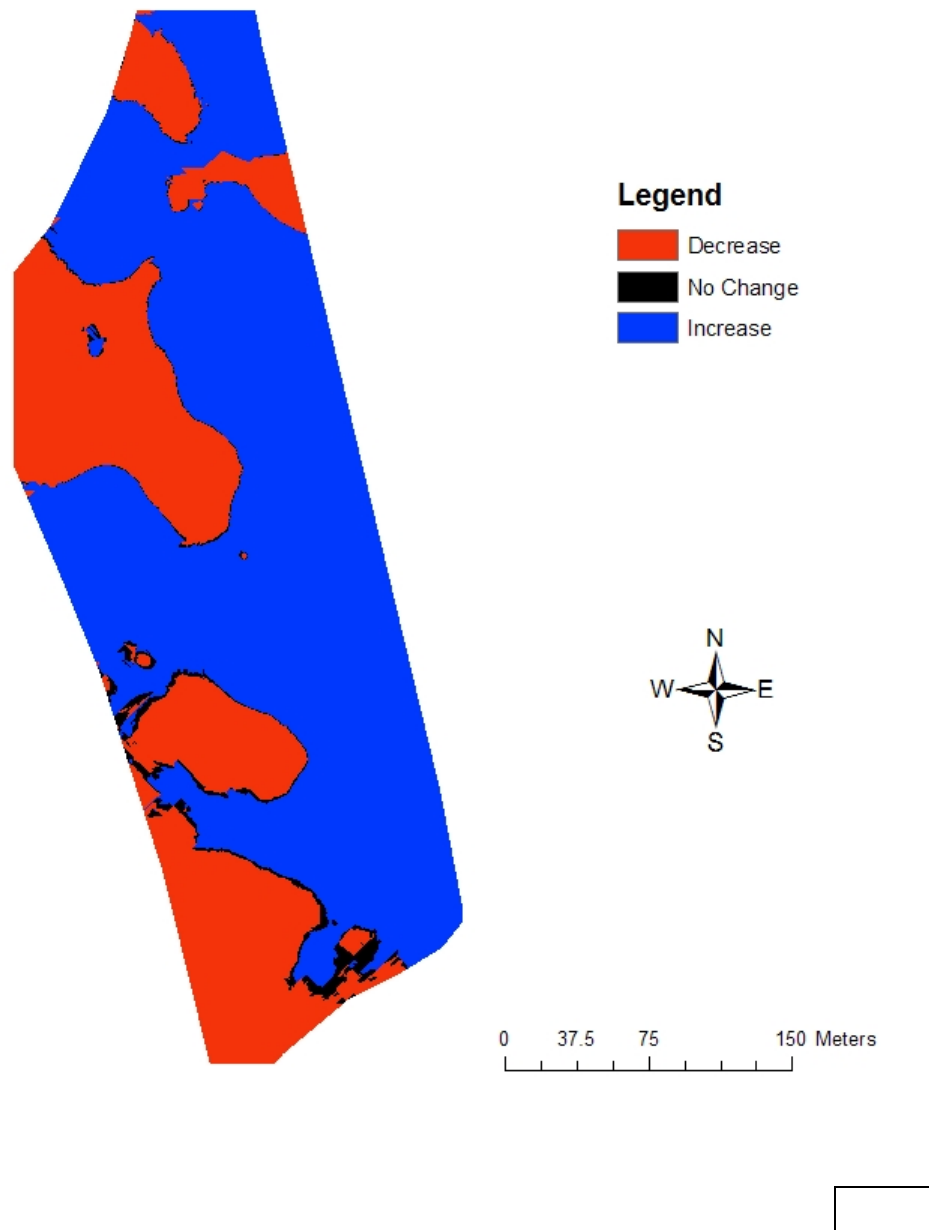
Figure 4.8: Conductivity change over time, Parcel 5, Mangote plantation



Another way to examine the data is to use the spatial analysis tools available with the ArcGIS platform. Using the Spatial Analyst extension, a GIS user can create a raster of the soil conductivity profile at two different times and then using the ‘Raster Calculator’ utility of Spatial Analyst, produce a surface which is the difference of the two original rasters. Such a raster is shown in Figure 4.9, which highlights the areas which have increased soil conductivity values and those that have decreased in conductivity during the time period separating the field runs. The input rasters used to create the raster difference shown in Figure 4.9 were taken during the EM38 I (June-July 2005) and EM 38 II (July-August 2005) field runs, and hence are taken 3 weeks apart. Figure 4.8 quantifies the areas of conductivity change and clearly displays those areas where salt may be accumulating on the surface of the parcel over the three week period (areas of conductivity increase). These areas can be identified and monitored over time, and appropriate measures taken if accumulation reaches an unacceptable level.

Although soil conductivity profiles were only constructed for the seven parcels shown above, this is just a preliminary step in the incremental addition of data to the GIS. The ultimate goal is to create similar maps for all parcels of the Mangote plantation, and eventually for the all the parcels on all farms of Azucarera Nacional. Creating such coverages over several years would allow managers to identify areas of consistent change, thereby identifying where there were management issues. It was also allow farm managers to identify those areas where EC levels were harmful to sugarcane production.

Figure 4.9: Conductivity change over time  
Raster difference, Parcel 5, Mangote Plantation



### **4.3.3 Conductivity changes over depth**

Another useful pattern to examine when creating soil conductivity maps is the difference between conductivity profiles from the surface to the root zone. Soil conductivity data was collected in both the horizontal and vertical dipole modes for all field data runs. As discussed in previous chapters, the horizontal readings give an indication of the surface soil profile, to a depth of 0.6m and vertical readings provide an indication of soil conductivity at a greater depth, giving an average of the conductivity up to 1.75m. Comparing the horizontal dipole with the vertical dipole gives the most effective indication of whether salt is moving upward or downward in the soil profile, and how well the processes of leaching and drainage are occurring in the field. When the surface profile shows generally lower values than the profile at a depth, then it is an indication that sufficient leaching is occurring and that salt is not moving up through the soil profile.

Figure 4.10 reveals that in general the conductivity at a depth (vertical dipole readings) for Parcels 23, 32 and 113 is higher than at the surface. This indicates that in general salts are being leached downward (either by rainfall or irrigation waters). Closer examination of the conductivity profile for Parcel 5, once again using the 'Raster Calculator' to obtain the difference between two rasters, reveals that there are areas in which the horizontal readings are in fact greater than the vertical readings (see Figure 4.11). It is important to monitor such regions for trends over the long term in order to identify soil salinization and implement mitigating measures before there is a strong decline of productivity.

Figure 4.10: Conductivity change over depth  
FDR2 Horizontal vs. Vertical

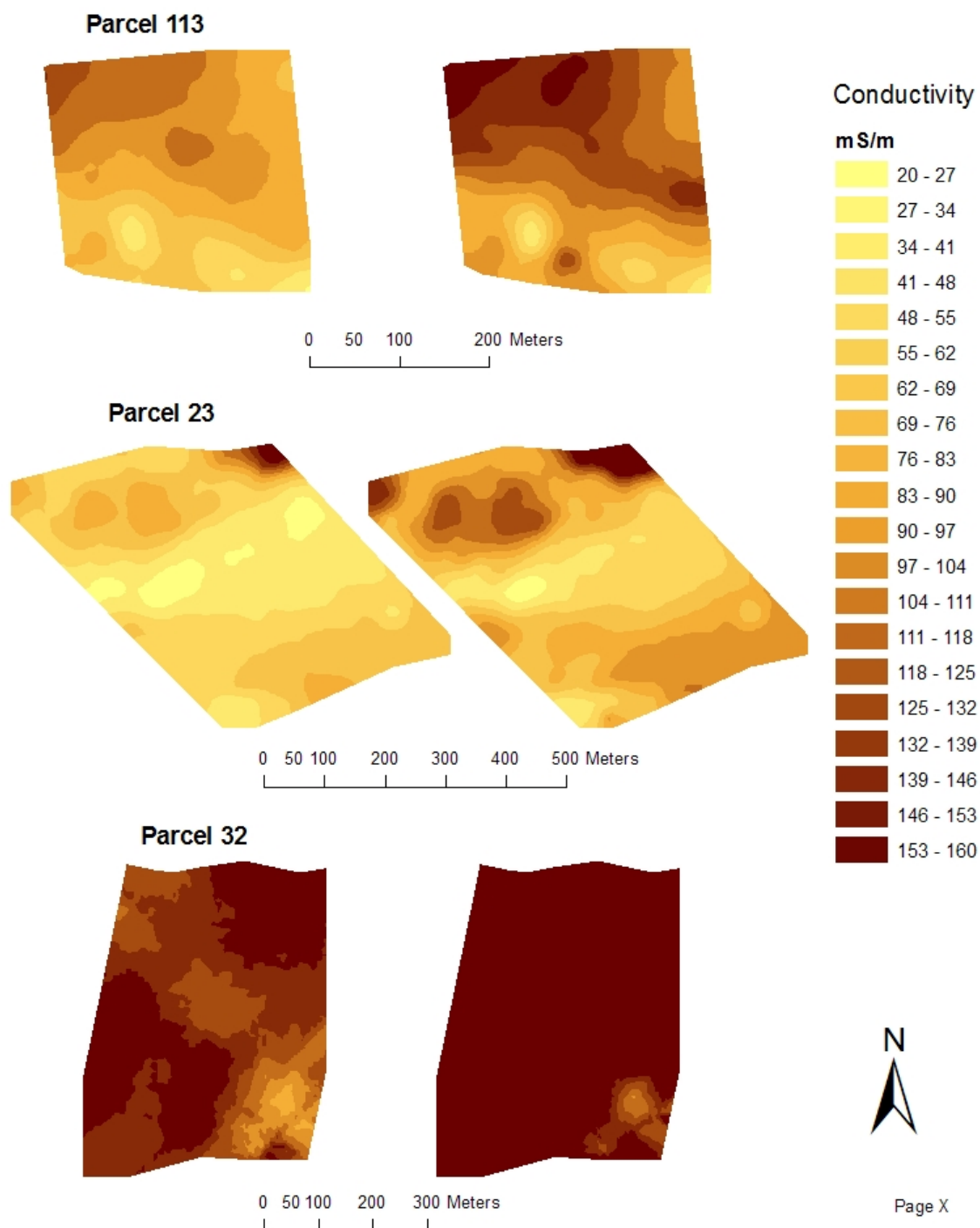
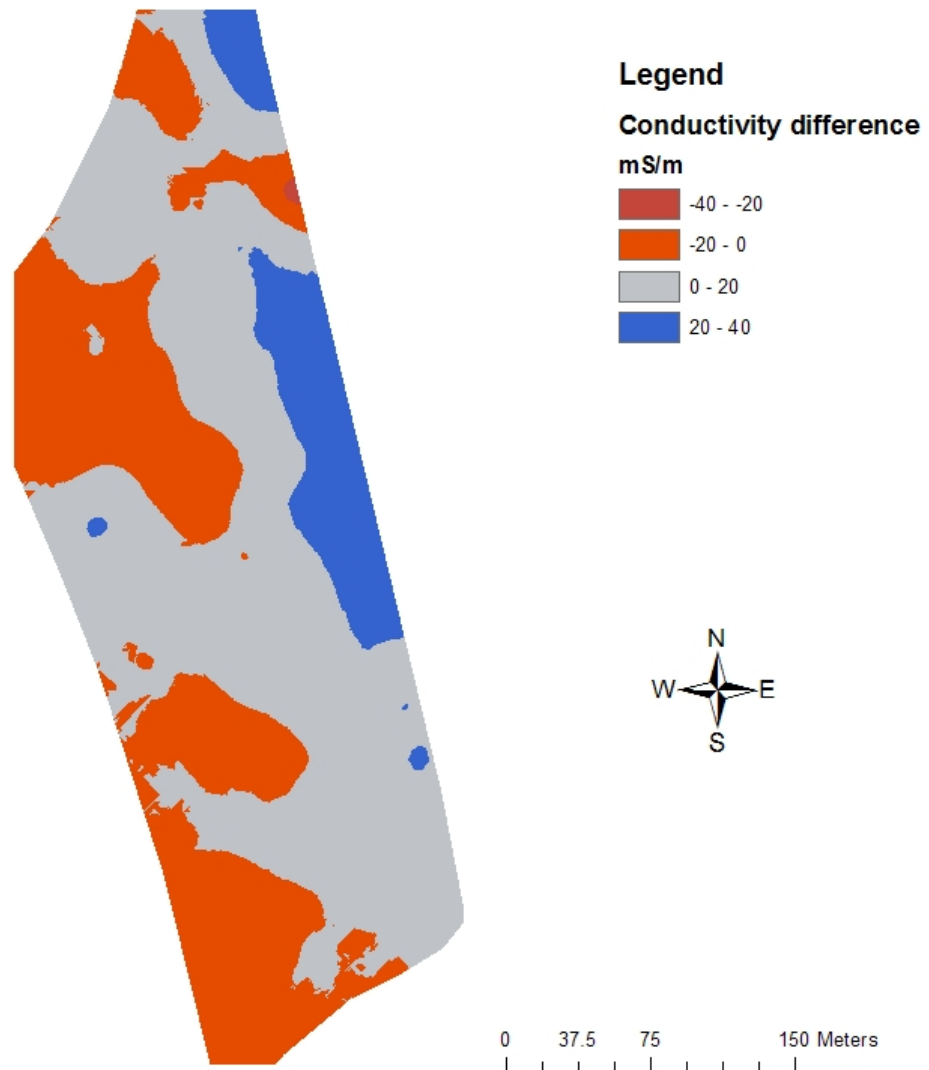
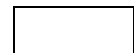


Figure 4.11: Conductivity change over depth  
Raster difference, Parcel 5, Mangote plantation



Data used: EM38 I Parcel 5, Horizontal - Vertical

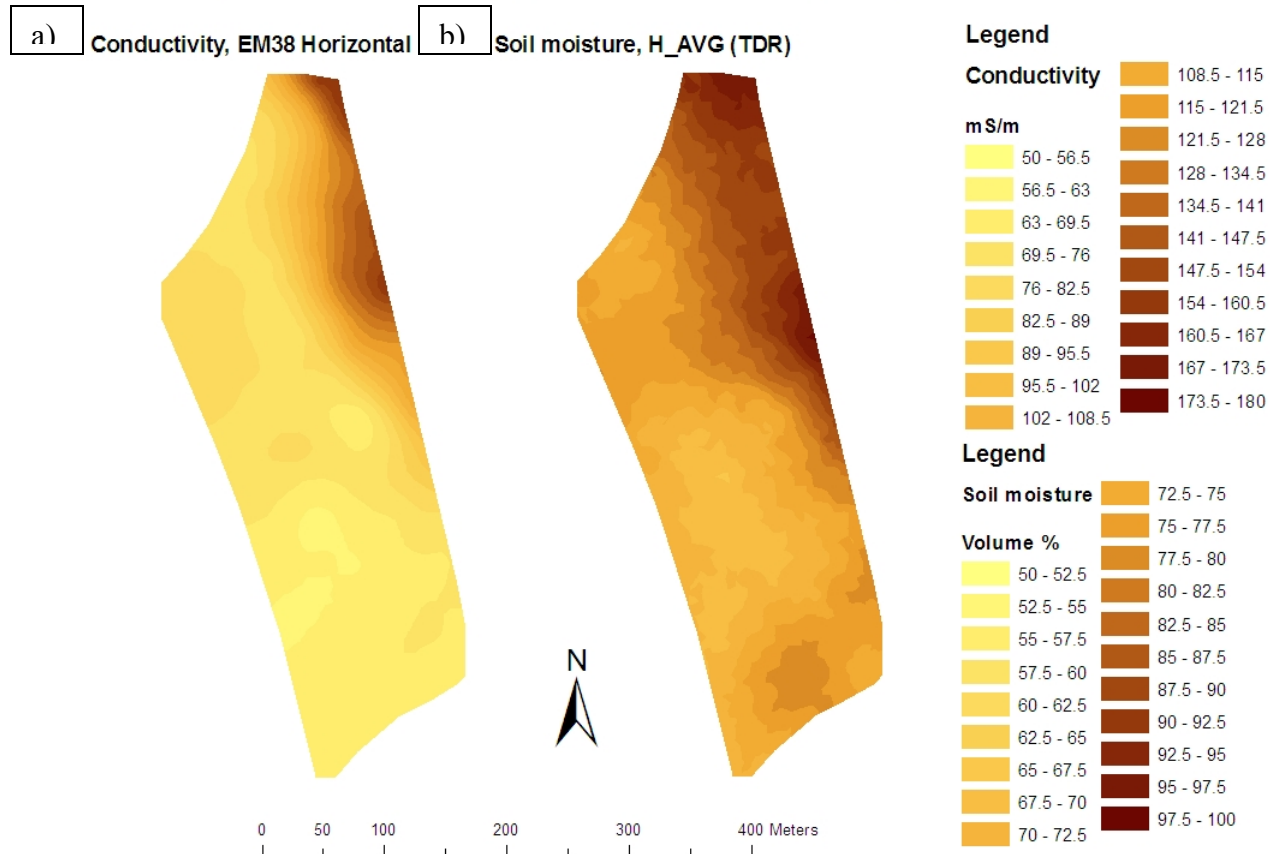


#### 4.3.4 Correlation of soil conductivity with moisture

##### a) Soil moisture

As discussed previously, soil conductivity readings are primarily a composite measure of soil moisture and salinity when the soil texture is constant. During the dry season, when the parcels are irrigated, the EM 38 instrument can also serve as a tool for identification of areas of high and low soil moisture; particularly in parcels that are known to be uniform in salinity. These measurements can be used in order to adjust irrigation water application, decreasing freshwater input where the soil is sufficiently irrigated. In order to assess the efficacy of the EM38 as a soil moisture measurement tool, soil conductivity readings were taken during the dry season in conjunction with independent soil moisture readings using a TDR300 soil moisture probe. The TDR readings give an indication of the relative soil moisture values over the field. The results of this field data collection were then interpolated and are shown in Figure 4.12.

Figure 4.12: Conductivity profile vs Soil moisture profile, Parcel 5

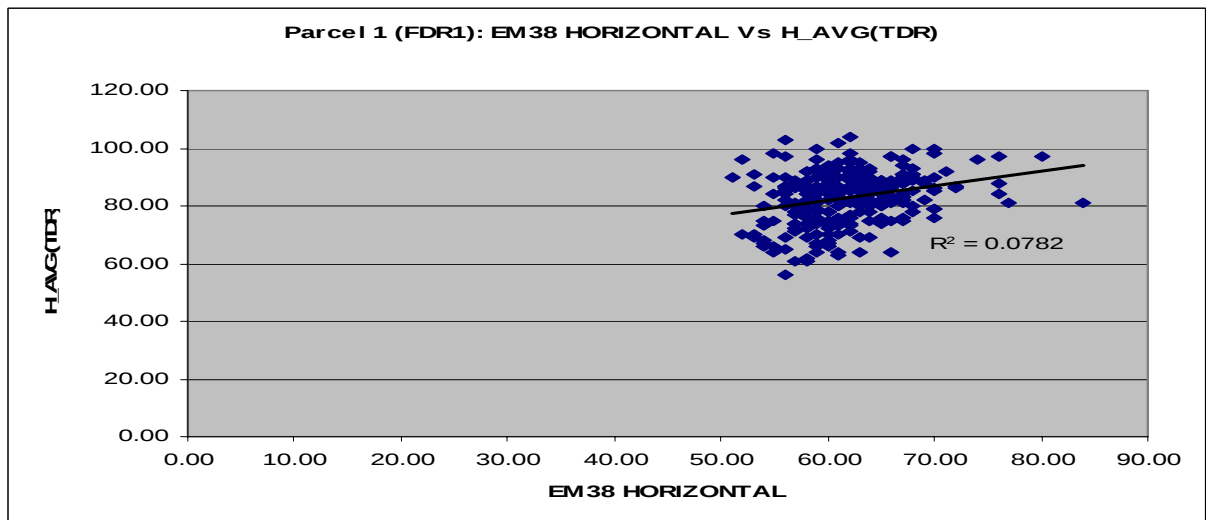
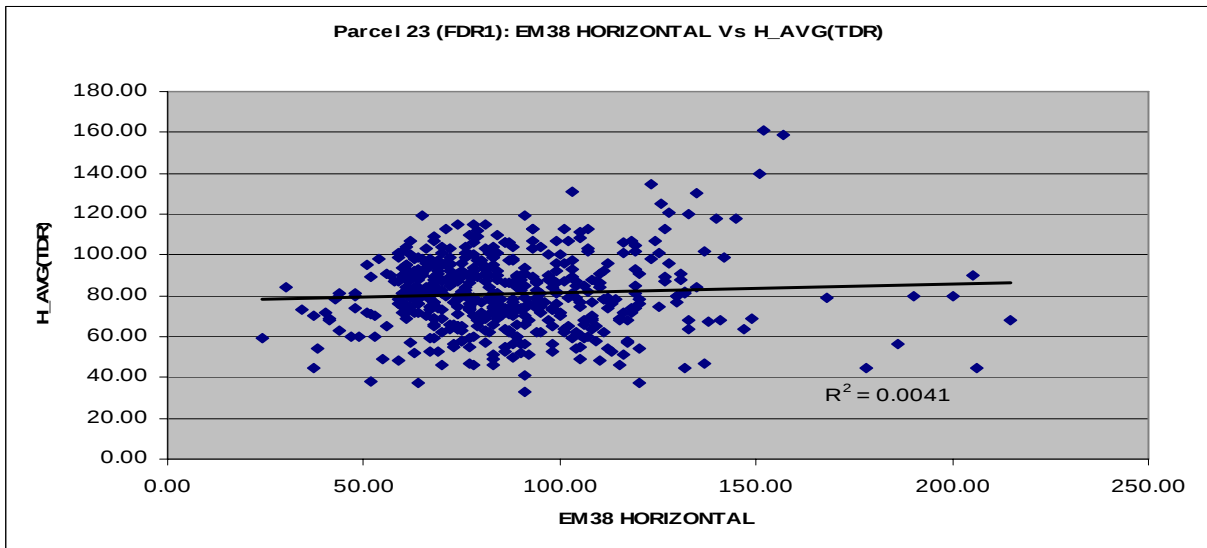
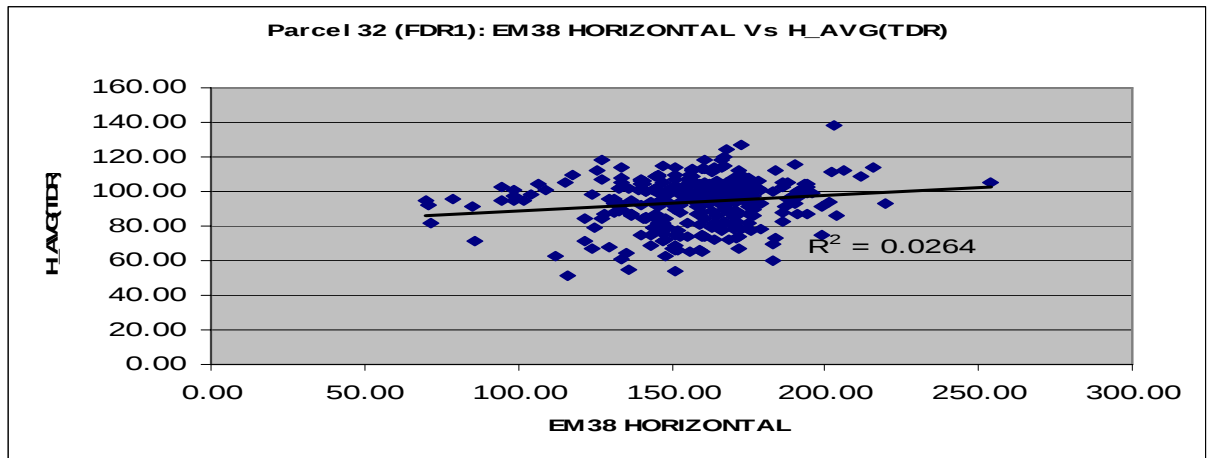




Upon examination of Figure 4.12, similar trends are observed between the conductivity profile and the TDR soil moisture profile. Although there are areas of elevated soil moisture and soil conductivity along the northeast edge of the field which correspond, the variation in the southern portion of the field, in particular a circular area of elevated moisture at the bottom center of the soil moisture profile does not show an accompanying peak in soil conductivity values in 4.12 a. This discrepancy between the soil moisture and soil salinity profiles is most likely due to an underlying property of the soil such as texture which influences both the soil moisture profile and the salinity of the soil. A soil texture change, such as elevated clay content, would not only increase the water holding capacity of soil but its salt content as well, which has been shown to linearly increase with clay content (Bajwa, Hira et al. 1983).

A simple linear regression between the soil conductivity readings and the soil moisture TDR readings also imply that in this case, only a very small percentage of the variation in the conductivity values can be explained by variation in moisture. Figure 4.13 below shows that  $R^2$  values for regression of the conductivity readings taken by the EM38 in the horizontal dipole mode versus soil moisture readings taken with the TDR 300 soil moisture probe show values which indicate that less than 10% of the variation in soil conductivity can be explained by variations in soil moisture. The correlation between these two properties was not expected to be as low as the  $R^2$  values displayed in the graphs of Fig 4.13 reveal, however this lack of correlation may be due to a variety of factors. One important consideration is that the soil moisture readings taken with the TDR may not be capturing the true spatial variability of this property in the field. That is soil moisture readings taken within only centimeters of each other may vary due to pockets of air present in the soil and the method by which the probes are inserted for example. However the primary reason that it is difficult to make a direct comparison between EM-38 and TDR 300 readings is the fact that the EM-38 gives an indication of the average conductivity of a much larger volume of soil than does the TDR 300 moisture probe. This is compounded by the fact that  $R^2$  values are notoriously sensitive to outliers (Quan, 1988) and hence the correlation between soil conductivity and soil moisture may actually be higher than suggested by Figure 4.13.

Figure 4.13 Correlation of Conductivity (EM38 hor) with Soil Moisture (TDR)



#### **4.3.5 Comparison of interpolation methods**

Three different interpolation methods were tested for their relative accuracy in creating soil property coverages. As the main goal of this project was to provide a practical tool for the examination of field conditions using maps in GIS, it was considered interesting to examine the difference between the accuracy and ease of use of the interpolation methods available through the Geostatistical Analyst extension of ArcGIS. As described in earlier sections, producing maps using a deterministic interpolator such as IDW is a relatively straightforward method in comparison to OK, which requires a more in depth understanding of the spatial variability of the data. Therefore three different surfaces were generated using the same data set for the first two field runs for all seven study parcels (14 data sets in total).

From Figure 4.14 it is evident that the IDW, OK and OKTR methods (Please refer to Chapter 3 for an explanation of how these surfaces were created) give very similar results in regards to the general pattern produced in the final surface, as expected. The only major visual difference in the coverages is that IDW produces coverages that are less “smooth” than those produced by OK and OKTR. That is, the coverages made using IDW display the “bull’s eye” effect surrounding individual data points; This is not considered an important limitation of the method and has little to no effect for the purposes of delineating management zones. The RMSE’s values for the various methods are displayed in Table 4.2. Considering these results, and the fact that RMSE’s values for the three methods do not differ by more than 3%, the author suggests that creating coverages with the ordinary kriging method without removing trends in the data or applying transformations(as in OKTR) , is the most practical option for GIS users at the plantation.

Figure 4.14: Geostatistical Interpolation Method Comparison, Parcel 5

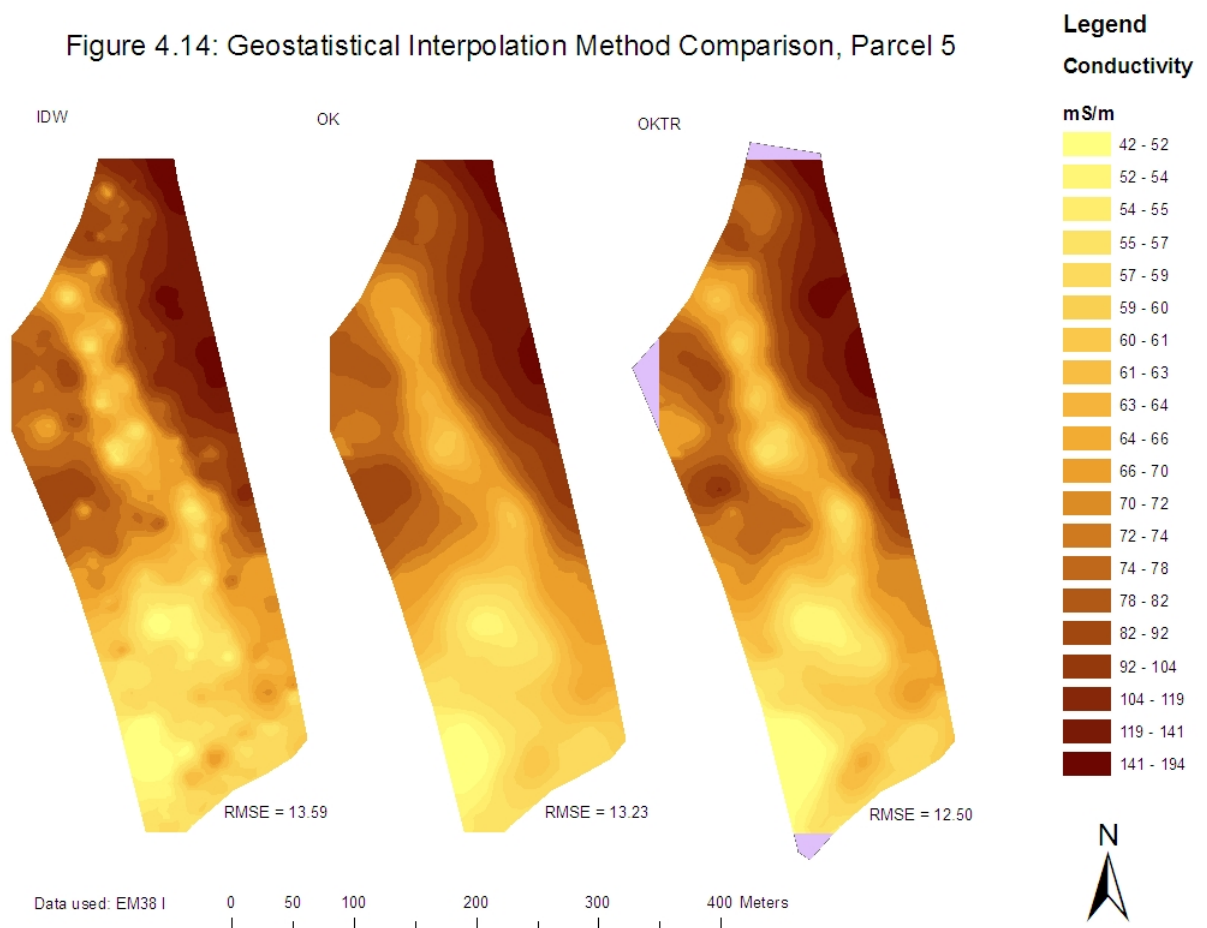


Table 4.2: RMSE's for IDW, OK and OKTR coverages

|             |                   | Parcel         | IDW          | OK RMSE      | OKTR RMSE    |
|-------------|-------------------|----------------|--------------|--------------|--------------|
| <b>EM38</b> | <b>Horizontal</b> | 1_jul19        | 6.27         | 5.90         | 5.92         |
|             |                   | 1_july5        | 4.48         | 4.79         | 4.60         |
|             |                   | 5_july13       | 11.02        | 10.14        | 10.16        |
|             |                   | 5_june17       | 13.59        | 13.23        | 12.50        |
|             |                   | 23_july8       | 16.79        | 17.76        | 18.36        |
|             |                   | 23_june13      | 15.60        | 17.52        | 16.35        |
|             |                   | 32_july28      | 30.09        | 28.72        | 28.93        |
|             |                   | 32_aug12       | 25.57        | 25.34        | 25.06        |
|             |                   | 89_july17      | 10.00        | 9.74         | 9.69         |
|             |                   | 89_june23      | 8.51         | 8.12         | 7.88         |
|             |                   | 113_jul15      | 13.65        | 13.07        | 13.03        |
|             |                   | 113_jun27      | 14.32        | 13.53        | 12.89        |
|             |                   | 146_aug17      | 25.56        | 23.12        | 22.99        |
|             |                   | 146_july20     | 23.28        | 24.20        | 24.24        |
|             |                   | <b>Average</b> | <b>15.62</b> | <b>15.37</b> | <b>15.19</b> |

## 4.4 Plant chlorophyll mapping

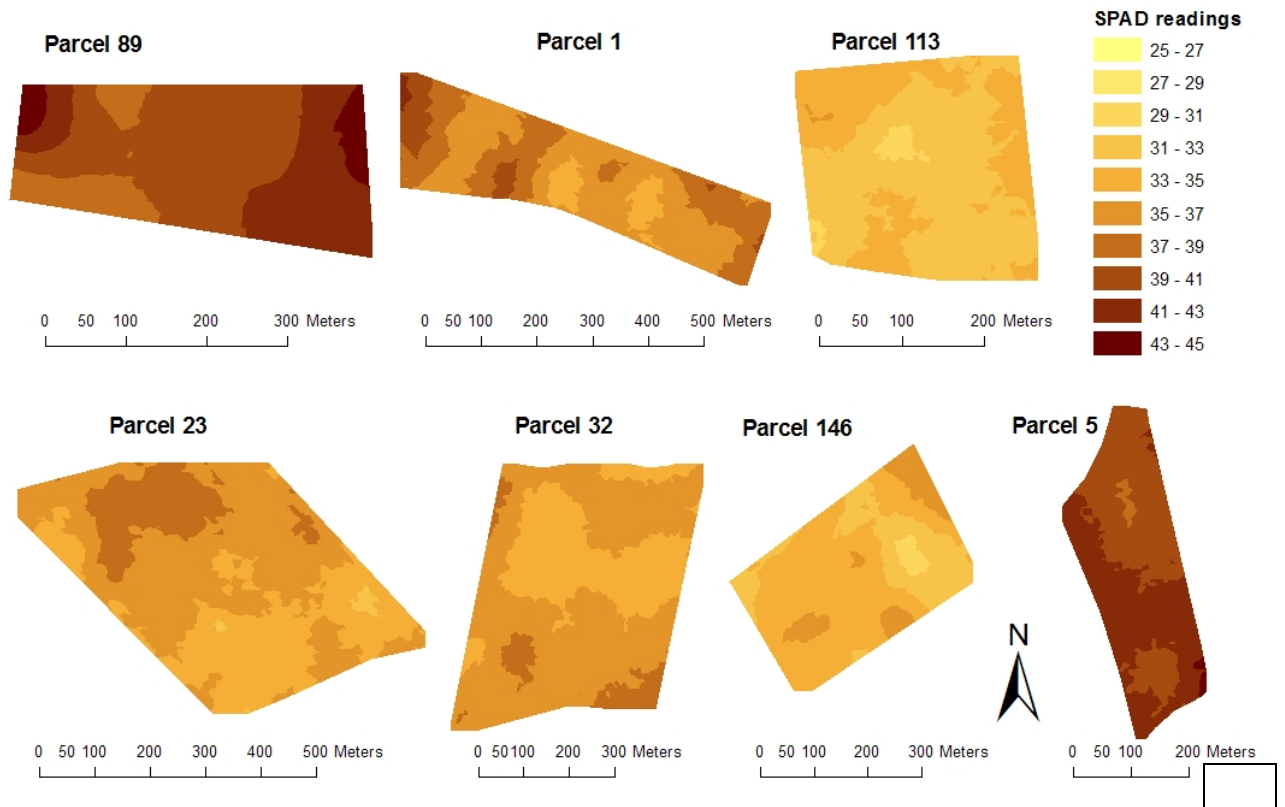
### 4.4.1 Nitrogen management zones

Plant chlorophyll mapping was undertaken in order to create maps of plant health status at a given time for each parcel. From Figure 4.15 it is evident that plant health, which is directly affected by the amount of chlorophyll present in the leaf, varies considerably both within individual parcels as well as among the study parcels. This heterogeneity, and the fact that large contiguous areas often show depressed chlorophyll readings in comparison to other areas, is strong motivation to adopt site-specific management practices. Using such maps, it is possible to identify areas that are receiving adequate fertilization and those areas that are showing nitrogen stress.

In general, the SPAD threshold value for adequate fertilization is between 35 and 40 SPAD units, with values below this range indicating inadequate fertilization and values above indicating excess (Vidal, Longeri et al. 1999). In Figure 4.15, Parcels 23, 32, 113 and 146 and parts of Parcel 1 all show nitrogen deficiencies with SPAD values in

the range  $\leq 35$  SPAD units and Parcels 5 and 89, as well as parts of Parcel 1, show adequate to excess fertilization with SPAD values up to 45. As fertilization on Mangote farm occurs as part of a scheme where nitrogen application is split between the seedling stage and at the early growth stage (after foliar analysis to determine N levels), maps such as the one shown in Figure 4.15, would be most useful just prior to the early growth stage application of fertilizer (Rice, Gilbert et al. 1993). Eventually, such maps could also be used in conjunction with variable rate technology (VRT) to increase nitrogen use efficiency and decrease yield variability by controlling fertilizer inputs based on the SPAD variation maps (Liang, Huang et al. 2004).

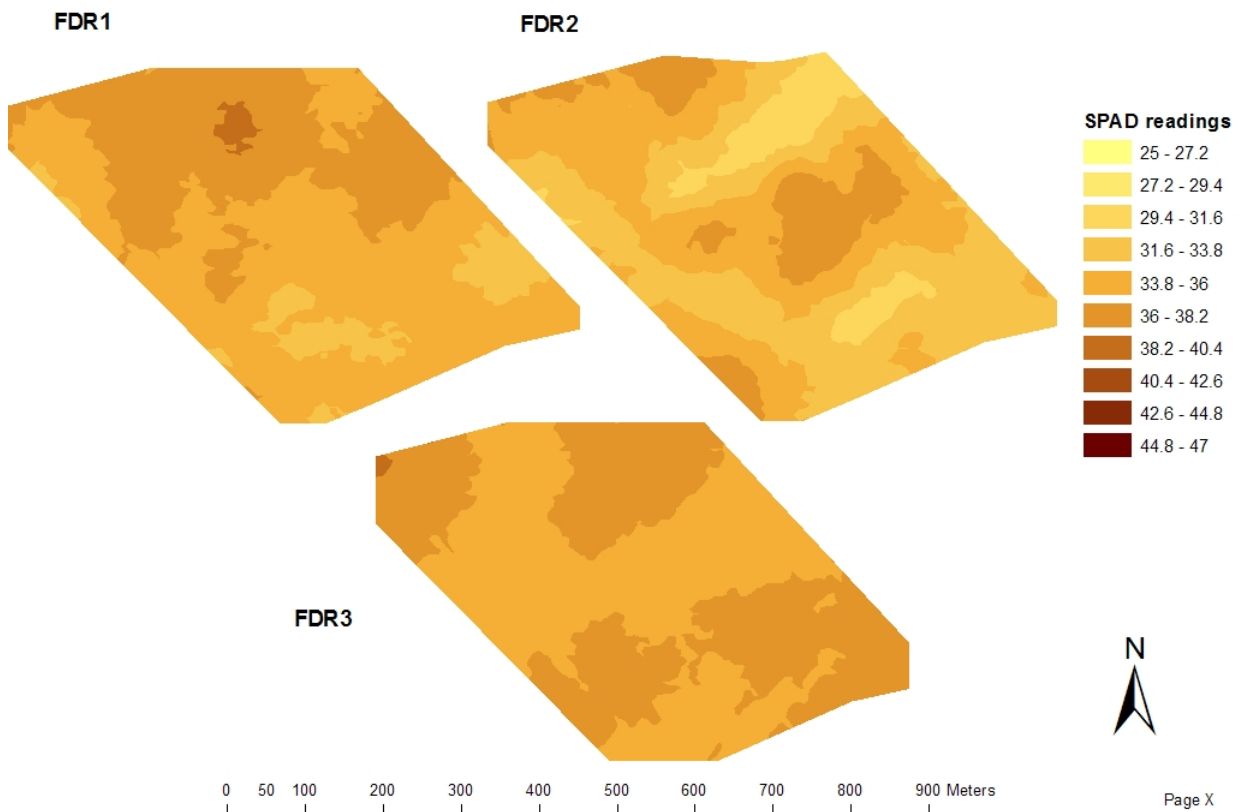
Figure 4.15: Plant chlorophyll profiles, SPAD readings for FDR1, All Parcels



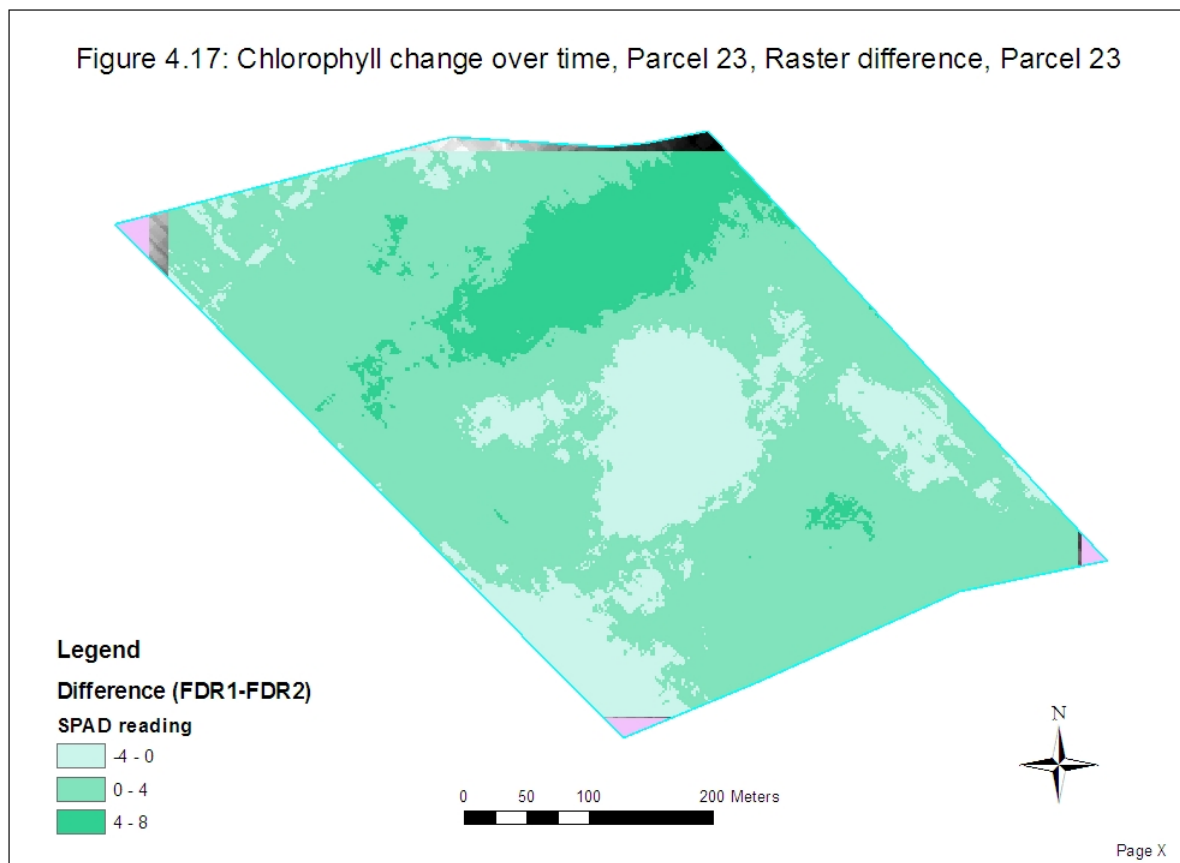
#### 4.4.2 Chlorophyll changes overtime

Unlike soil conductivity profiles, plant chlorophyll profiles are much more variable over time, as indicated by Figure 4.16. These changes over time of plant chlorophyll patterns in the field can be explained by a variety of factors. Plant chlorophyll is not only affected directly by nitrogen uptake (Noh, Zhang et al. 2003) but also shows variable changes as crop maturation occurs (Murdock, Jones et al. 1997). Furthermore anything that causes plant stress, such as water or nutrient deficiencies, or excess soil salinity will affect the SPAD readings (Murdock, Jones et al. 1997). Although SPAD measurements are much more variable over the field season, unlike soil conditions which are more stable, the literature suggests that a thorough characterization of plant nitrogen deficiency at an *early* growth stage is most effective to predict yield (Simões, Rocha et al. 2005).

Figure 4.16: Plant chlorophyll zones at different times, Parcel 23



As was done with soil conductivity readings over time, in Figure 4.9, it is possible to display the areas where chlorophyll changes have occurred over time using the Raster Calculator. The map shown in Figure 4.17 was derived by subtracting the plant chlorophyll profile raster created from the FDR1 collection (started Dec. 6, 2005) from the raster of the FDR 2 collection (started Jan. 25, 2006). The figure therefore shows the change in plant chlorophyll which occurred in the field between these two dates. The lightest areas of Figure 4.17 represent those in which chlorophyll levels have dropped during the time period and the darkest areas show where chlorophyll levels have risen. This information can be used to target and redirect fertilizer applications where they are most necessary.



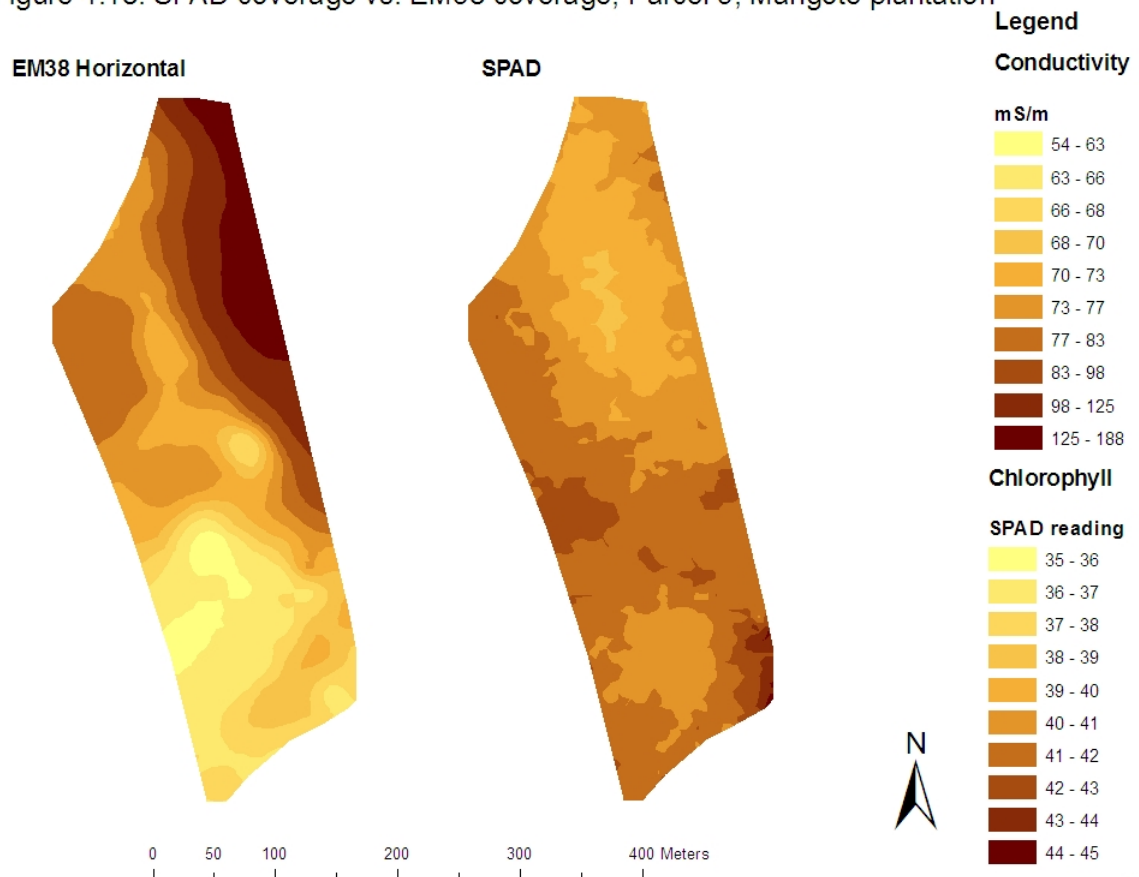


#### **4.4.3 Correlation of plant chlorophyll with other properties**

##### **a) Soil conductivity**

From a comparison of Figure 4.15 with Figure 4.6, it is interesting to note that parcels 23, 32, 113 and 146 which show relatively depressed SPAD readings, are also those with the highest soil salinity. Parcels 1, 5 and 89 on the other hand, which are considered parcels with the most fertile soils show SPAD readings in the high range, implying a that there is a relationship between the salinity level of the soil and plant vigor. In light of the fact that soil conductivity is directly affected by both soil salinity and soil moisture, both of which have an effect on plant health, some correlation was expected to be found between soil EM38 readings and leaf chlorophyll measurements made with the SPAD meter. Upon examination of Figure 4.18 however, it is evident that there is not a strong agreement between the spatial patterns of soil conductivity and plant chlorophyll over the field for Parcel 5. Although the extremely saline portion of the field in the northeast corner of Parcel 5 also displays depressed SPAD readings, the spatial extent of these areas do not completely overlap and the area of highest salinity does not correspond to the area of lowest plant chlorophyll. This lack of correlation implies that there are other factors (such as nutrients other than N and other biotic and abiotic factors) affecting the distribution of plant chlorophyll readings over the field, and that the variation cannot just be explained by the variation in salinity.

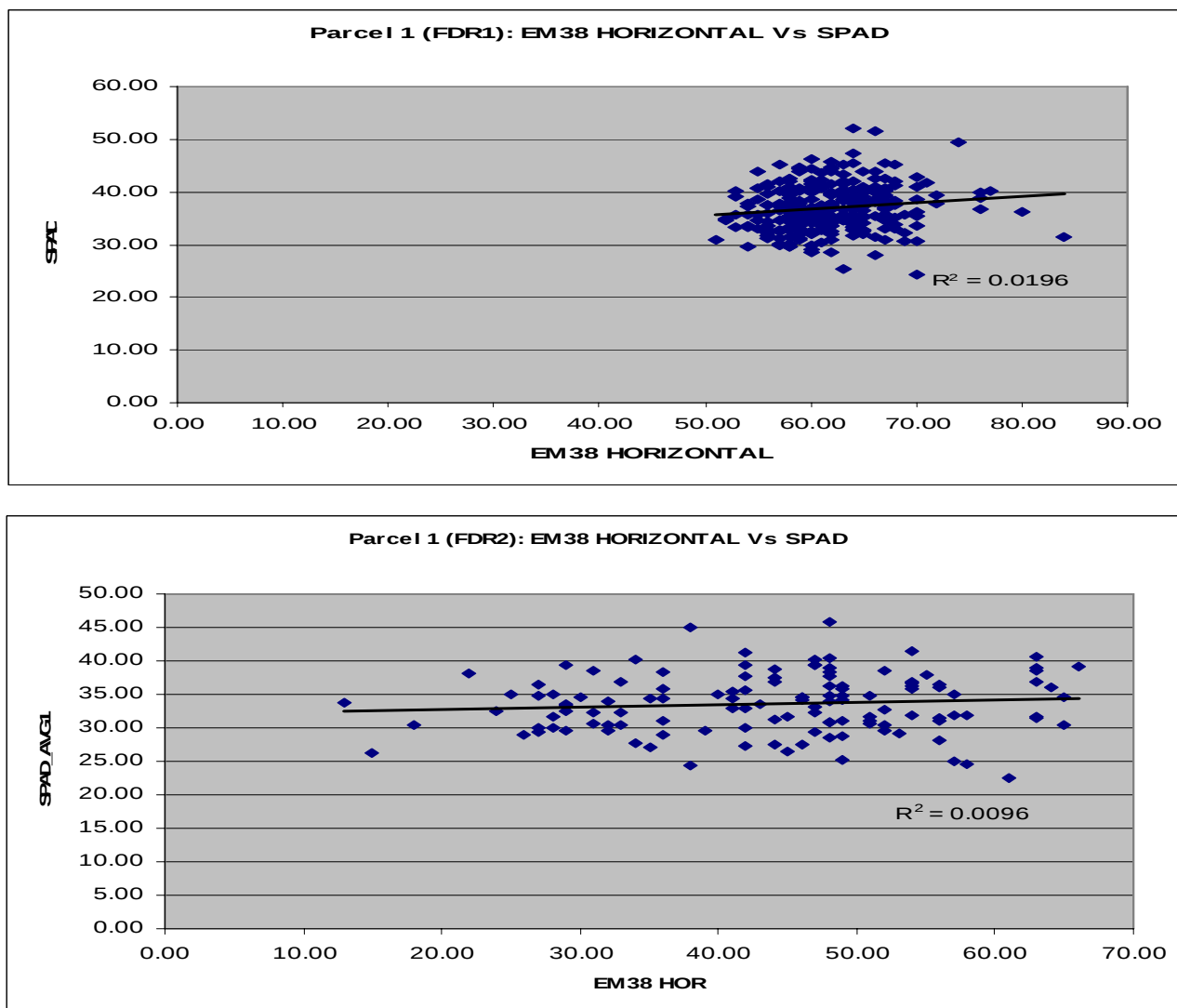
Figure 4.18: SPAD coverage vs. EM38 coverage, Parcel 5, Mangote plantation

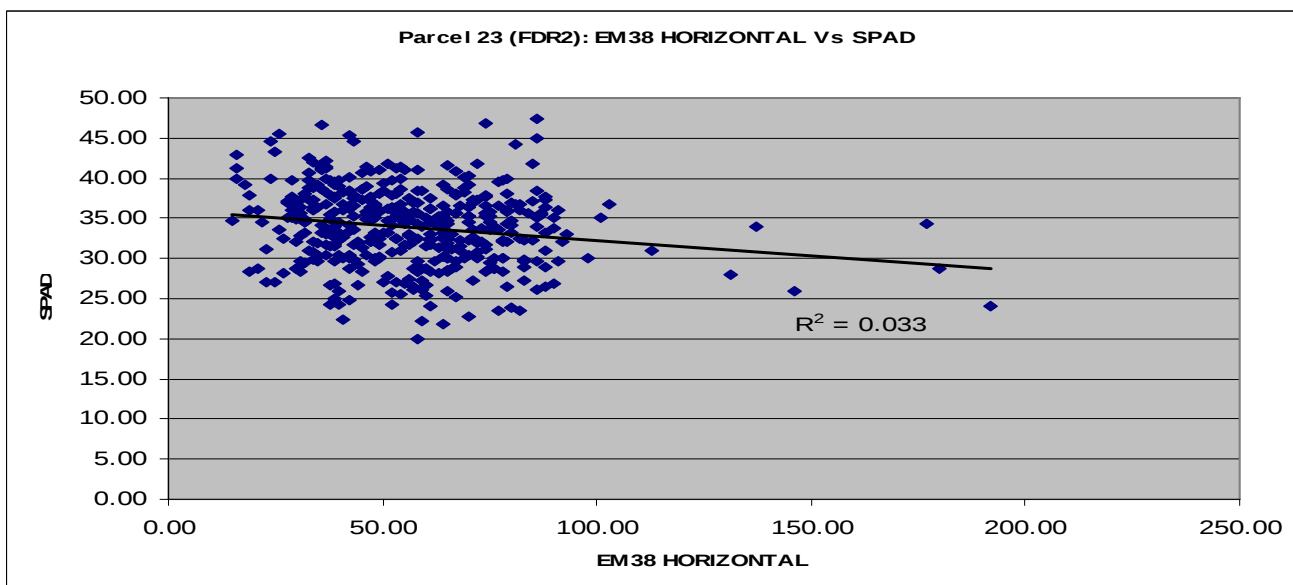
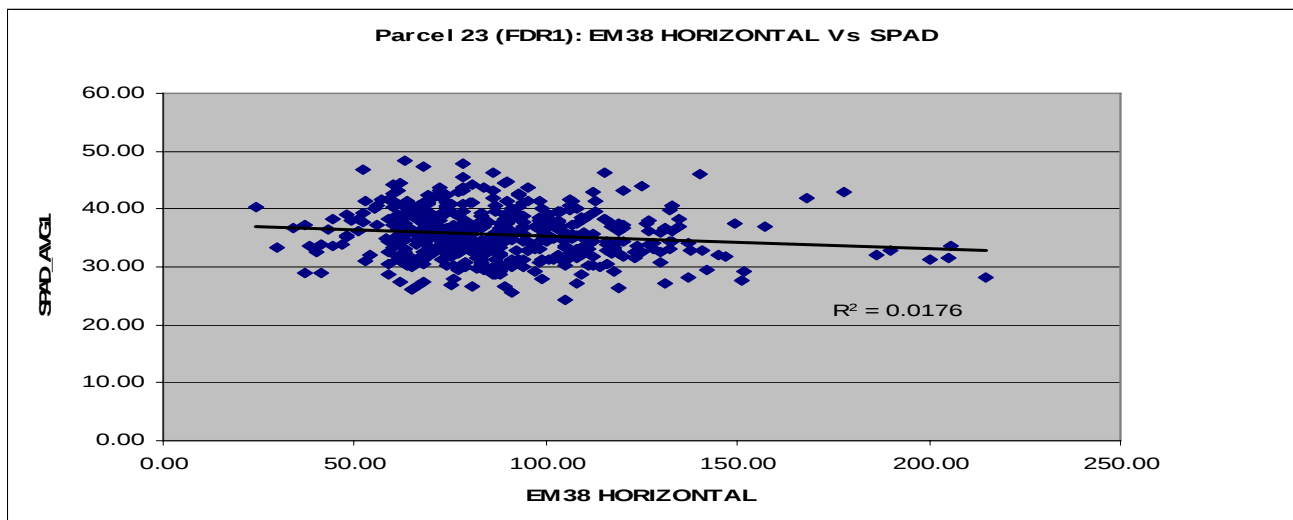


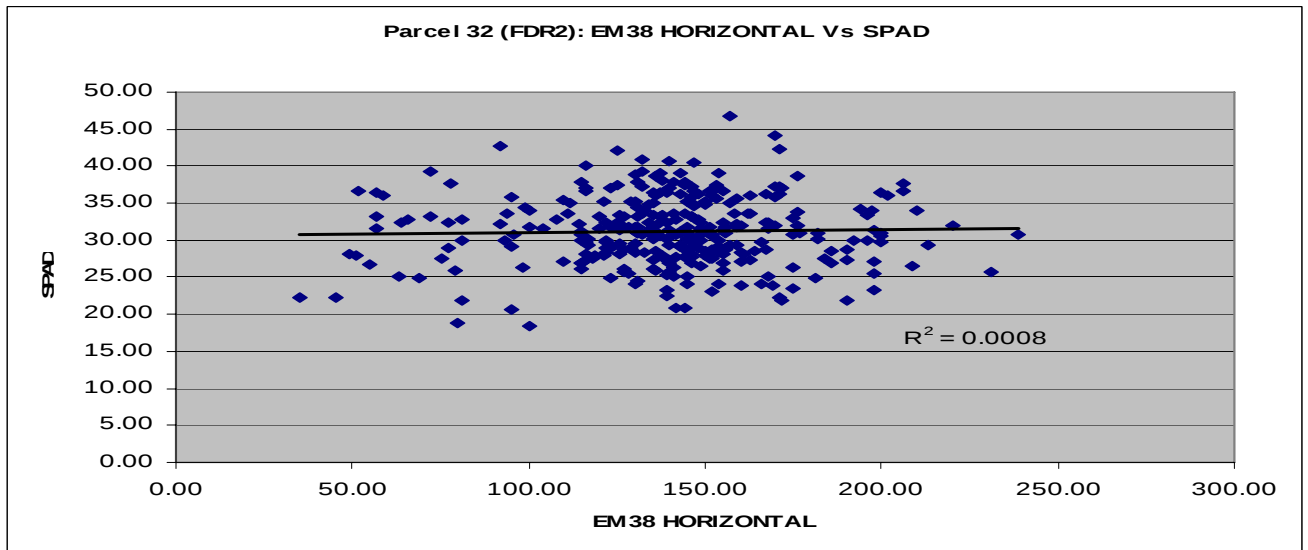
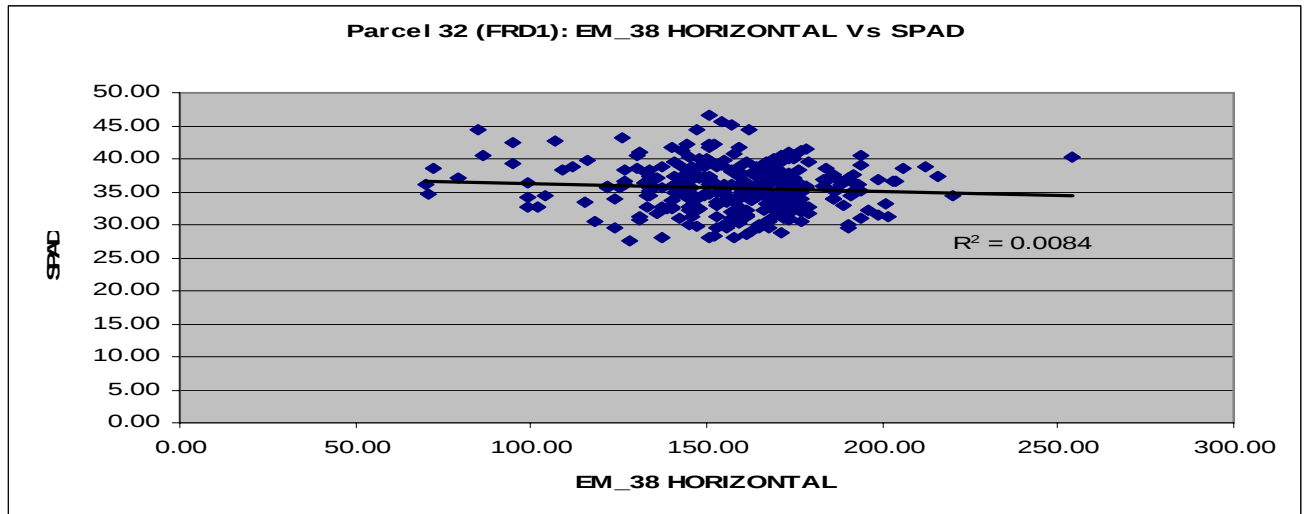
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The lack of spatial correlation is confirmed by plotting the soil conductivity measurements (EM 38 horizontal) against the plant chlorophyll readings (SPAD) taken at the same point. The  $R^2$  values derived from these plots also imply that there is little correlation (see Figure 19). It is noted that these findings do not reveal that there is *no* correlation between SPAD and EM38 readings; however the analysis implies that the interrelation between the two parameters is confounded by other variables. Most importantly, SPAD readings are most likely disproportionately sensitive to fertilizer applications over the variations in plant health caused by underlying soil conditions.

Fig. 4.19: Correlation of plant chlorophyll (SPAD) with Soil conductivity (EM38 hor)







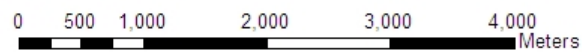
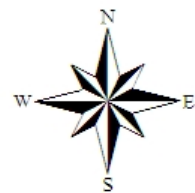
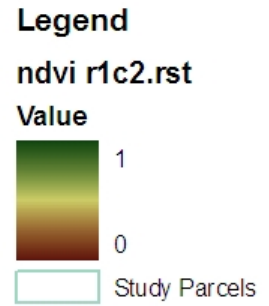
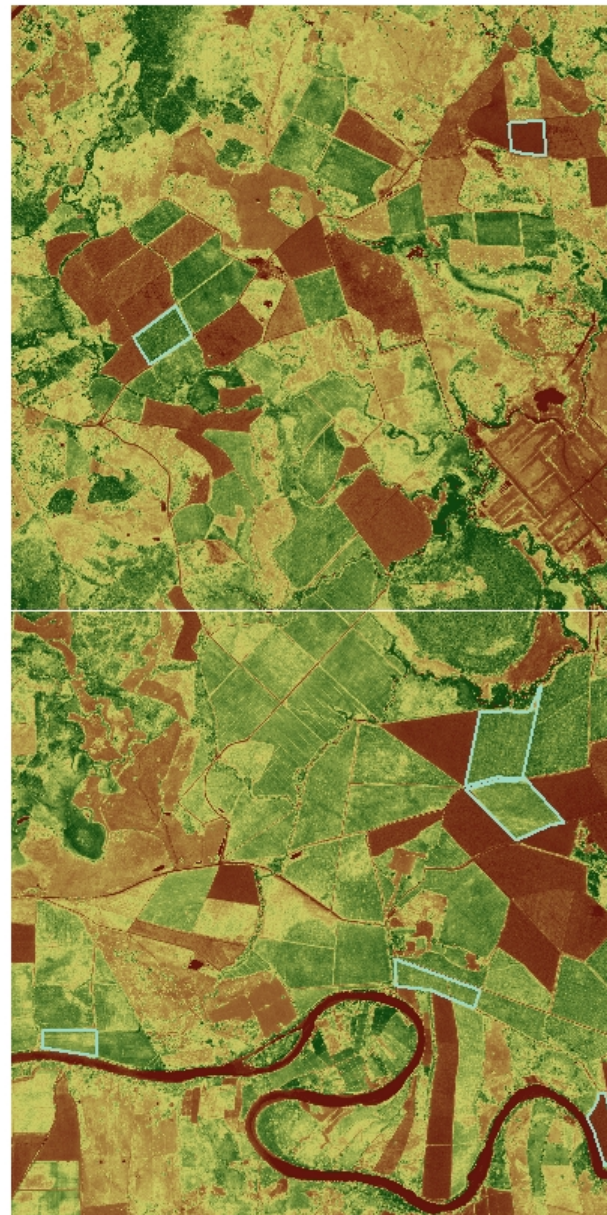
## b) Plant chlorophyll mapping using NDVI

A high resolution Quickbird image was obtained of the study area near the end of the 2006 harvest season (Acquisition data: February 3<sup>rd</sup>, 2006). The image capture covered 79km<sup>2</sup>, covering the spatial extent of Mangote farm and all of the seven study parcels where detailed sampling occurred. From Figure 4.20 which shows the NDVI coverage obtained of the Mangote plantation, one can clearly identify bare soil parcels (which appear red) in contrast to planted parcels (which appear green). The fine resolution of the image (60 cm for panchromatic and 2.44 m for multispectral) also allows identification of within parcel plant health variability. As discussed in Chapter 2,

NDVI values for this scene should vary from 0 to 1, where 0 indicates the absence of vegetation while an increasing positive value indicates an increase in the plant density and vigor. These images are very useful for identifying areas of plant stress and decreased biomass within a field. From the NDVI coverage shown in the right in Figure 4.21 areas of decreased plant health are clearly visible in streaks appearing in the south area of the parcel as well as at the northern tip of the field. Another useful way to use NDVI coverages is as a direct indicator of plant nitrogen status which can potentially save the time required to collect ground-based data (Lamb 2000).

# Figure 4.20: NDVI Index , Mangote Plantation

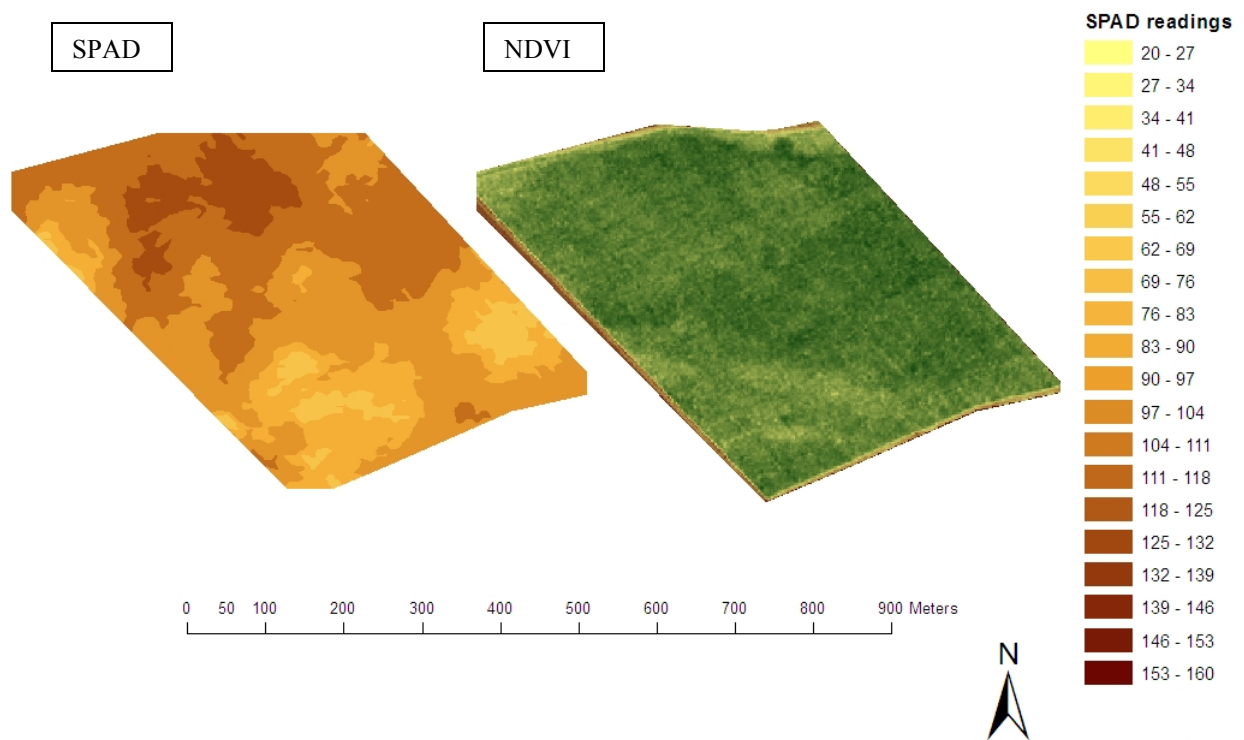
Derived from QuickBird Satellite Imagery



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Comparing the SPAD plant health coverage with the NDVI coverage of Parcel 23, both shown in Figure 4.21, there is some correspondence between areas of low chlorophyll observed in both coverages. The area of depressed SPAD values in the south region of the plant chlorophyll coverage shown on the left of Figure 4.21 are matched by the area of evident plant stress and/or decreased biomass evident in the south corner of the NDVI coverage shown on the right. However the problem with trying to find a direct correlation between the NDVI coverage and the coverage created using the plant chlorophyll readings obtained from the SPAD meter is that, whereas NDVI is sensitive to the leaf area index (LAI) and soil background reflectance, the SPAD meter does not capture these variations (Daughtry, Walthall et al. 2000).

Figure 4.21: Chlorophyll profile vs. NDVI coverage, Parcel 23



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It is also recognized that it is often difficult to isolate the parameters that contribute to stress measured by the chlorophyll meter due to the complexity of interrelated factors (Ahmad, Reid et al. 1999). This reveals that, although several studies



(Jackson 1986; Pinter and Moran 1994; Wiegand, Anderson et al. 1996; Blackburn 1999, Lamb 2000) have shown correlations between nitrogen deficiencies detected in the field with those obtained from satellite imagery derived NDVI, the chosen method of characterizing plant chlorophyll conditions over the field is not appropriate. That is, taking point SPAD readings over the entire field, rather than intensively on smaller plots, is not conducive to finding a correlation between SPAD and NDVI.

One limitation of the SPAD data is that a large number of random observations must be averaged to reduce variability and make statistical comparisons meaningful and hence there is a point sampling limitation in obtaining SPAD readings (Adamsen and Pinter, 1999).

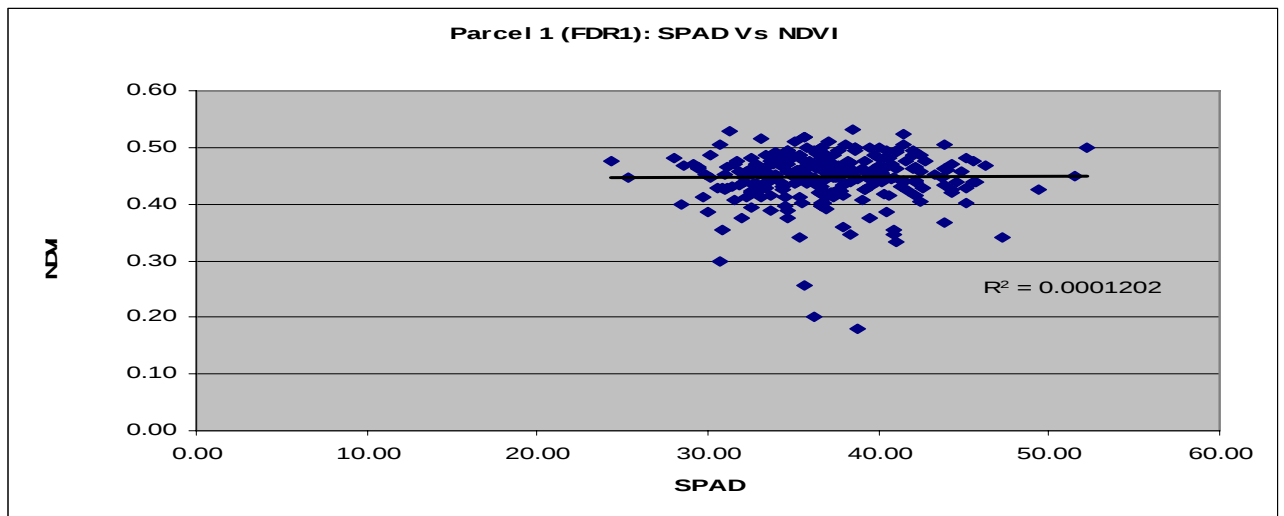
Another principle challenge encountered in trying to correlate SPAD readings with NDVI values is the small variation in the SPAD variations. SPAD readings typically range from 25 to 50 with the majority of readings falling in the 30 to 45 range. In order to detect such a subtle variations in chlorophyll concentrations for the purposes of scientific studies artificial nitrogen deficiencies are often created by applying many times the normal amount of nitrogen to test plots (Feng, Hu et al. 2005). This results in pronounced and detectable differences in chlorophyll concentrations which can be correlated to NDVI.

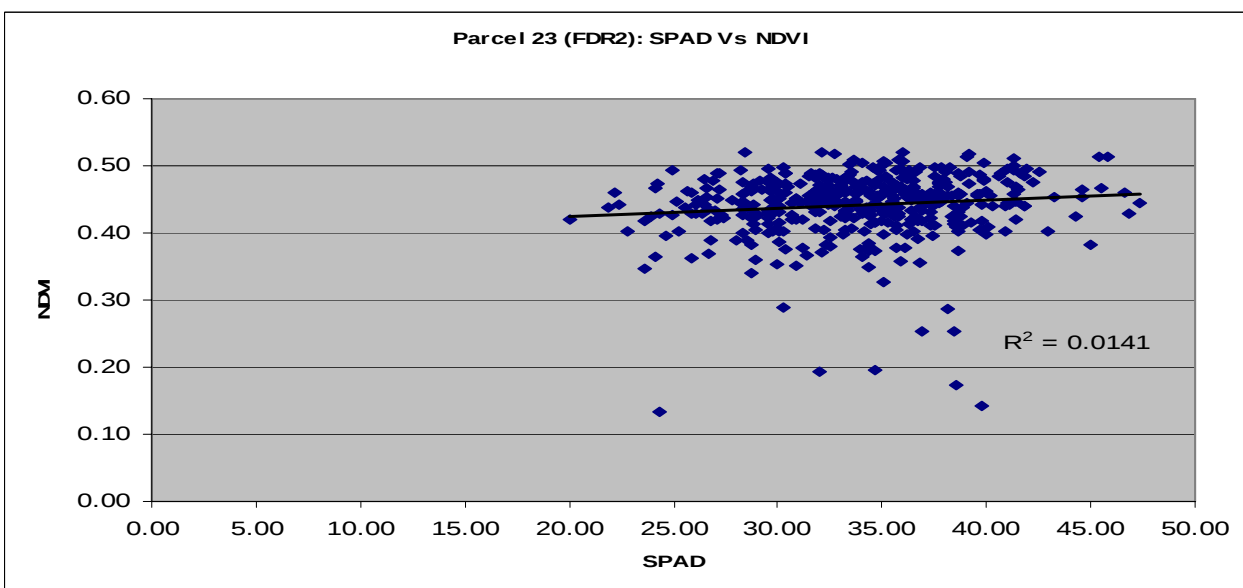
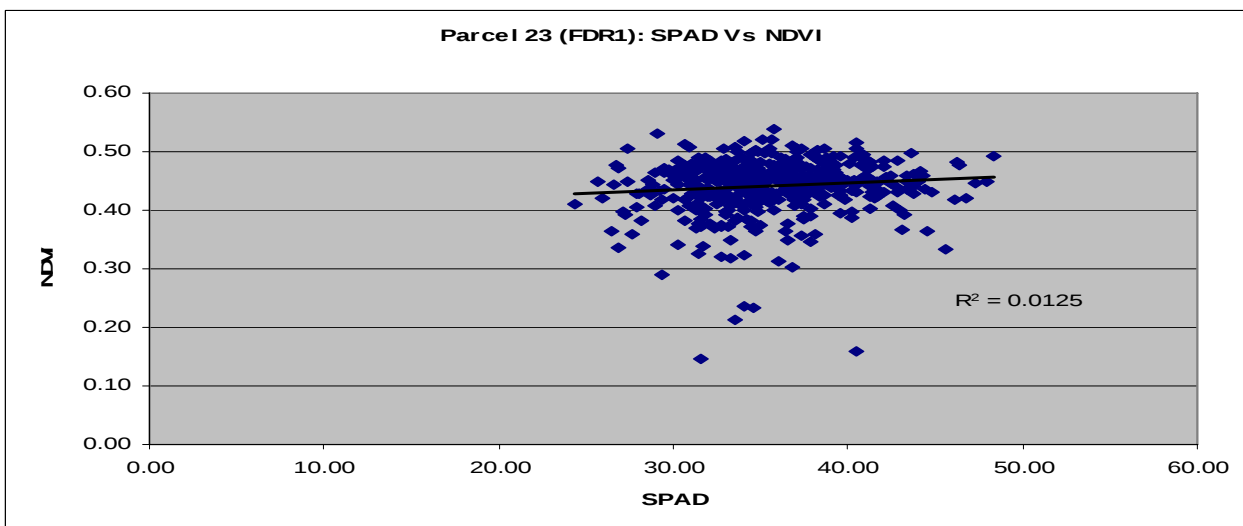
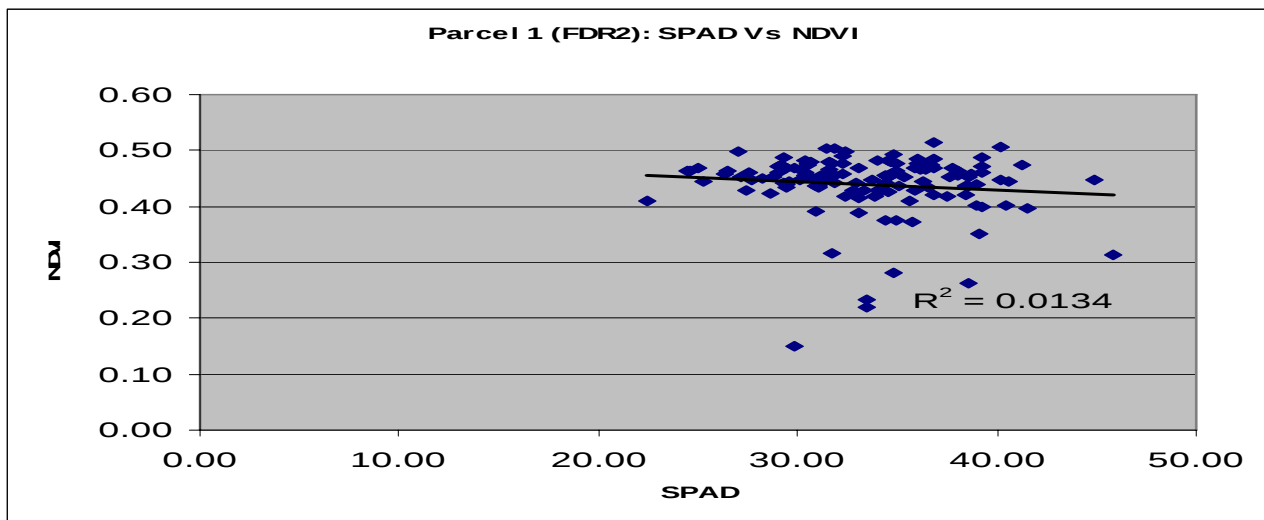
Furthermore the problem is compounded by the fact that SPAD readings are sensitive to leaf water status, time of measurement (morning vs. afternoon) as well changes in irradiance; One study showed that SPAD values varied by up to 4 units over the course of a day in the same well watered maize plants and that small changes in leaf water status and irradiance caused changes of 2-3 units. This becomes an issue because SPAD readings must be taken over a certain time period (the length of which depends on the size of the field) whereas NDVI readings are taken in 'one-shot'. This is very significant considering the narrow range of SPAD readings and one can see from Figure 4.17 that the greatest difference in SPAD readings from one field run to the next is within 8 units.

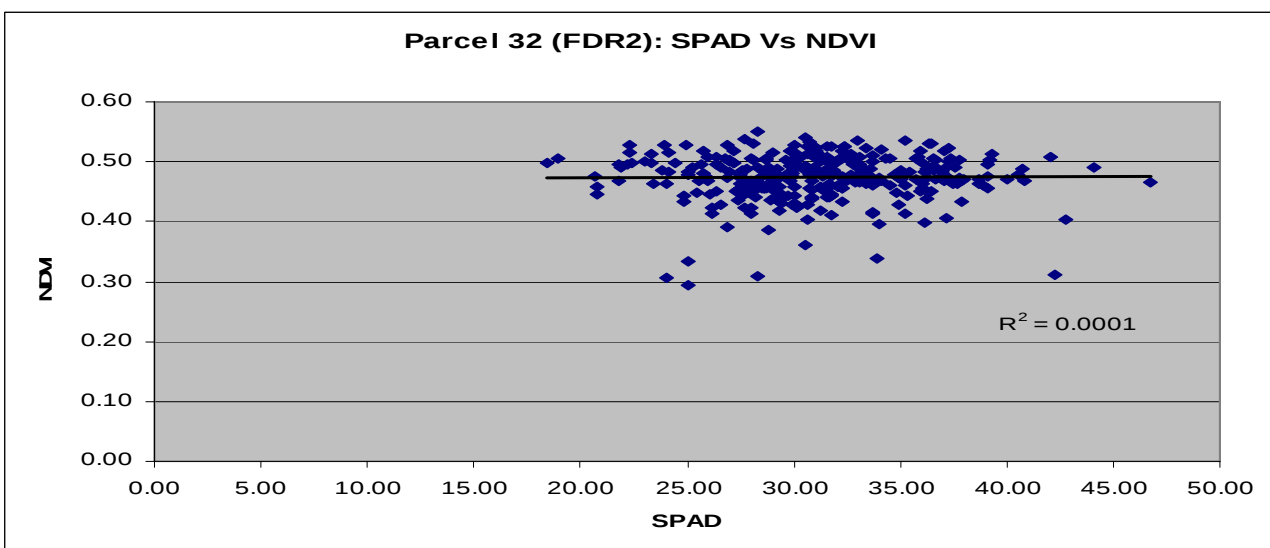
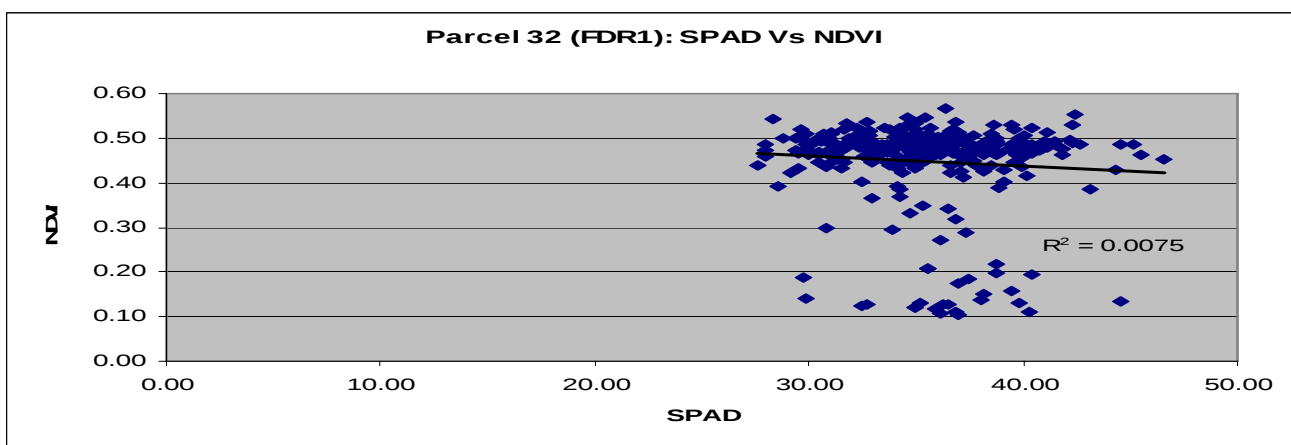
The use of point sampling analogous to using a very small treatment plot also limits the use of using Quickbird imagery in this study, as corroborated by another similar study (Wu, Wang et al. 2007). When correlations have been attempted between

SPAD readings and aerial imagery for scientific purposes, treatment plots are created where usually at least 30 readings are taken per plot and at least 3 readings are taken per leaf in order to overcome SPAD variations, which implies over 90 readings are taken per plot (Le Bail, Jeuffroy et al. 2005). These findings are further confirmed by Australian researchers, that note that the link between remotely sensed data (such as NDVI) and crop biophysical parameters (such as leaf chlorophyll content) seem only to work in the context of research projects involving single or localized collection within fields (Lamb 2000) It is concluded that work remains to be done in correlating the information found in these images with ground-truth data such as plant chlorophyll readings from a SPAD meter, collected at the field scale for practical applications. Regardless, high resolution satellite imagery used to produce NDVI coverages, remains a very useful tool to visually identify nutrient deficient problem areas in the field.

Fig 4.22: Correlation of plant chlorophyll (SPAD) with Spectral response (NDVI)







#### **4.5 Precision Agriculture: implementation challenges and considerations for the future**

Although much PA development and implementation has taken place in a ‘high-tech’ context in developed countries, the principles of PA are equally applicable to developing countries in which access to resources may be limited. Although investment in equipment such as the ground based monitoring tools used in this project, or high resolution satellite imagery may not be possible for many developing country producers, knowledge of environmental heterogeneity can certainly be used to adjust management with simpler means, without recourse to high-tech PA options, (Booltink, van Alphen et al. 2001) Furthermore, many developing countries, and at the least large scale producers within those countries *do* have access to the technologies required to make PA work. Far from being a luxury, the use of spatial information to reduce uncertainty is essential to accelerate change, promote economic development and reduce environmental impacts in the developing world (Cook, O'Brien et al. 2003).

The key to successful implementation of site-specific management in the global south is promoting access to resources and training (Kalluri, Gilruth et al. 2003). Furthermore, a Geographic Information System created for crop management is only as powerful as its users and in order for the system to be of use, it must be accessible to all farm managers and to those individuals directly involved with the management of inputs, so that local knowledge in spatial analysis and use of the software continues to evolve (Ramasubramanian 1999). For this reason, frequent meetings were held with all farm managers and administrators at the plantation on a regular basis during the creation of the initial database. The ultimate success of the project will depend on continued communication between as GIS users at the central office, farm managers and those workers directly applying inputs in the field.

Ultimately economic incentive will be the driving force for larger scale implementation and as discussed in Chapter 2, the incorporation of environmental costs into economic analysis will play an important role. Although the Panamanian government does not yet have legislation in place to control allowable pollutant concentrations in agricultural effluents, charging farmers for irrigation water is one step towards controlling excessive water use for irrigation purposes. Continued large scale efforts to

put precision agriculture principles into practice have the potential to influence other countries in the region to adopt similar initiatives.

The International Center for Tropical Agriculture has also identified the potential value of spatial information in developing agriculture and assessed the reality of providing spatial information in developing countries (Cook, O'Brien et al. 2003). They conclude that although systems which rely on expensive sampling or monitoring may not always be appropriate, especially for smaller land-owners and subsistence farmers, management schemes which take into account local knowledge of environmental variance can be used to create larger management zones which can be administered accordingly. According to Maohua (2001), development should be an evolutionary process and it should be possible to demonstrate PA ideas in larger farms through agricultural technical extension systems with contact services to farmers even when local expertise are not directly available (Maohua 2001). Furthermore, donor funded programs have great potential to increase provision of spatial information to regional and national governments. In fact, some specific development initiatives aim to provide the basic infrastructure for more democratic knowledge sharing, such as the recent World Bank project to establish a platform GIS in Latin America (World Bank 2002).

Stafford (2000) identifies three important drivers that will provide the motivation for widespread uptake of precision agriculture; environmental legislation, traceability and public concern over farming practices. The fourth driver may be public aversion to genetic modification of crops whereby PA provides an alternative means to reduce and optimize the use agrochemicals (Stafford 2000). All of these studies demonstrate that the principle challenge of future worldwide PA adoption is therefore effective global information sharing, capacity building of PA related technologies and recognition and economic reward for PA environmental benefits.

## **CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Summary**

The goal of this project was to establish a Geographic Information System for the management of crop information at the Azucarera Nacional sugarcane plantation in the Republic of Panama. In order to accomplish this, the first step was to create a base map of Mangote plantation with up-to-date boundaries of each parcel. Secondly, seven individual parcels on the farm were chosen and detailed field sampling was carried out on these parcels. This discrete data was interpolated using Geostatistical methods in order to create continuous coverages of two properties: soil conductivity and plant chlorophyll. The soil conductivity maps can be used as a tool to create salinity management zones. Issues concerning the change of salinity over time and over depth were explored. Two interpolation methods, IDW and OK, were then compared. Plant chlorophyll maps were constructed and their usefulness was discussed; the possible correlation between plant chlorophyll measurements and soil conductivity as well as NDVI was also explored. Finally, some of the challenges encountered during PA implementation were discussed and the several considerations related to future PA implementation were explored.

### **5.2 Conclusions**

1. Creating digital maps of land holding is a promising tool for sugarcane crop management in Panama, particularly for creating a central system for resource management in general and for crop data management (storage and retrieval) in particular.
2. Thematic maps are a useful analysis tool in GIS to improve crop management, specifically for identifying contributions to low yield and for modeling management scenarios.
3. Parcels 1, 5 and 89 can be considered non-saline to slightly saline. Parcels 23, 113, 146 contain zones of slight, moderate and very high salinity; these parcels provide an example of the merit of creating management zones. Parcel 32 can be considered extremely saline.

4. There is sufficient soil salinity variation within some parcels studied to justify creation of soil salinity management zones.
5. Salinity management zones were relatively stable over the study period.
6. In general, the conductivity at a depth is higher than at the surface (EM 38 vertical readings are higher than EM 38 horizontal readings) for the study parcels. This implies that adequate leaching is, at this time, occurring and that salts are not accumulating at the surface, although longer periods of time must be studied in order to substantiate this.
7. The root mean square errors obtained using IDW as opposed to OK do not vary greatly (RMSE of 15.62 for IDW and 15.19 for OKTR) and hence it is recommended to use the simpler and more 'user-friendly' option of IDW for the purposes of creating raster coverages for PA application at the study site.
8. Plant chlorophyll maps reveal nitrogen deficiencies in five out of seven parcels (Parcels 23, 23, 113, and 146, as well as in parts of Parcel 1).
9. Plant chlorophyll readings show significant within parcel variability as well as variability over the study period.
10. Little to no spatial correlation was found between conductivity readings and plant chlorophyll readings although in general parcels with extreme salinity showed depressed chlorophyll values.
11. NDVI coverages derived from high resolution satellite imagery were deemed useful for the visual identification of plant stress. The chosen point sampling scheme for creating field-scale plant chlorophyll coverage using SPAD meter readings was shown to have little to no correlation with the NDVI coverages. As explained in section 4.4.3, this is likely due to the sensitivity of SPAD readings to a variety of factors as well as point sampling limitations.
12. Although PA implementation faces particular barriers in the developing country context, in the author's opinion increased environmental awareness and decreased costs will act as a facilitator for more widespread adoption.



### 5.3 Suggestions for Further Research

A vast amount of data was collected over the two years of field data collection. Due to time constraints, much of the data was not used for analysis purposes related to the current dissertation, however all of the data is available to the GIS user for future analysis and in order to build historical records. This data includes soil texture, pH, soil organic content, and soil micronutrients as well as soil conductivity and plant chlorophyll data that were interpolated but not presented directly for discussion. Furthermore, a thorough examination of the use of spectral indices using the high resolution Quickbird image should be undertaken and alternative sampling schemes explored. Sampling for other parcels should be sub-divided into zones in order to cut down on sampling time. Future investments at the plantation should include a yield monitor and a combine with GPS in order to collect 'on-the-go' soil conductivity readings. Climatic data should also be included on a regular basis in the system. Farmers in the area can also pool their resources in the future with other large land owners in order to purchase aerial imagery of the area. Training and collaborations should also continue between Universidad Tecnológica de Panama and the company.

ArcGIS is continually evolving as a tool for spatial analysis. ArcInfo 9.3 will offer the possibility of carrying out much more sophisticated regressions and comparisons between surfaces. Also, from within the ArcView Spatial Analyst extension it is possible to use the Avenue programming language, as well as ModelBuilder to explore various land use scenarios, based on the relationships between yield and other relevant mapped parameters, before actually implementing such scenarios on the field.

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## A1 EM-38 1

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
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| 1      | 3      | 3     | 545359 | 900418 | 66       | 64         |
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| 1 | 65 | 3 | 545767 | 900280 | 81 | 72 |
| 1 | 66 | 1 | 545776 | 900225 | 83 | 71 |
| 1 | 67 | 1 | 545766 | 900363 | 65 | 59 |
| 1 | 67 | 2 | 545774 | 900354 | 62 | 58 |
| 1 | 67 | 3 | 545772 | 900348 | 67 | 63 |
| 1 | 68 | 1 | 545786 | 900269 | 69 | 57 |
| 1 | 68 | 2 | 545788 | 900281 | 59 | 48 |
| 1 | 68 | 3 | 545792 | 900289 | 60 | 55 |
| 1 | 69 | 1 | 545791 | 545299 | 63 | 58 |
| 1 | 69 | 2 | 545790 | 545311 | 64 | 58 |
| 1 | 69 | 3 | 545796 | 545326 | 60 | 56 |
| 1 | 70 | 1 | 545800 | 900333 | 59 | 58 |
| 1 | 70 | 2 | 545803 | 900343 | 67 | 62 |
| 1 | 70 | 3 | 545806 | 900350 | 71 | 58 |
| 1 | 71 | 1 | 545839 | 900338 | 70 | 68 |
| 1 | 71 | 2 | 545836 | 900317 | 65 | 63 |
| 1 | 71 | 3 | 545834 | 900310 | 68 | 66 |
| 1 | 72 | 1 | 545830 | 900306 | 65 | 60 |
| 1 | 72 | 2 | 545824 | 900301 | 60 | 60 |
| 1 | 72 | 3 | 545822 | 900290 | 66 | 61 |
| 1 | 73 | 1 | 545817 | 900281 | 59 | 62 |
| 1 | 73 | 2 | 545814 | 900269 | 64 | 56 |
| 1 | 73 | 3 | 545810 | 900261 | 59 | 58 |
| 1 | 74 | 1 | 545808 | 900259 | 57 | 54 |
| 1 | 74 | 2 | 545804 | 900251 | 61 | 59 |
| 1 | 74 | 3 | 545799 | 900240 | 60 | 65 |
| 1 | 75 | 1 | 545796 | 900231 | 61 | 62 |
| 1 | 75 | 2 | 545791 | 900219 | 70 | 62 |
| 1 | 75 | 3 | 545790 | 900213 | 54 | 54 |
| 1 | 76 | 1 | 545815 | 900201 | 52 | 51 |
| 1 | 76 | 2 | 545827 | 900208 | 67 | 66 |
| 1 | 76 | 3 | 545831 | 900213 | 68 | 59 |
| 1 | 77 | 1 | 545834 | 900218 | 66 | 55 |
| 1 | 77 | 2 | 545837 | 900229 | 59 | 57 |
| 1 | 77 | 3 | 545839 | 900241 | 61 | 50 |
| 1 | 78 | 1 | 545837 | 900249 | 57 | 56 |
| 1 | 78 | 2 | 545838 | 900259 | 58 | 57 |
| 1 | 78 | 3 | 545845 | 900265 | 65 | 54 |
| 1 | 79 | 1 | 545849 | 900283 | 69 | 55 |
| 1 | 79 | 2 | 545850 | 900292 | 68 | 60 |
| 1 | 79 | 3 | 545854 | 900304 | 67 | 58 |
| 1 | 80 | 1 | 545857 | 900308 | 65 | 66 |
| 1 | 80 | 2 | 545860 | 900318 | 65 | 56 |
| 1 | 80 | 3 | 545867 | 900328 | 57 | 60 |

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|---|----|---|--------|--------|----|----|
| 1 | 81 | 1 | 545906 | 900319 | 76 | 65 |
| 1 | 81 | 2 | 545902 | 900310 | 58 | 60 |
| 1 | 81 | 3 | 545897 | 900303 | 59 | 59 |
| 1 | 82 | 1 | 545896 | 900298 | 60 | 51 |
| 1 | 82 | 2 | 545888 | 900280 | 63 | 54 |
| 1 | 82 | 3 | 545887 | 900269 | 64 | 57 |
| 1 | 83 | 1 | 545886 | 900262 | 63 | 51 |
| 1 | 83 | 2 | 545883 | 900252 | 59 | 60 |
| 1 | 83 | 3 | 545879 | 900239 | 62 | 58 |
| 1 | 84 | 1 | 545876 | 900232 | 64 | 57 |
| 1 | 84 | 2 | 545871 | 900221 | 60 | 58 |
| 1 | 84 | 3 | 545868 | 900207 | 61 | 57 |
| 1 | 85 | 1 | 545870 | 900203 | 65 | 58 |
| 1 | 85 | 2 | 545865 | 900187 | 63 | 56 |
| 1 | 85 | 3 | 545863 | 900187 | 51 | 49 |
| 1 | 86 | 1 | 545890 | 900168 | 66 | 64 |
| 1 | 86 | 2 | 545898 | 900188 | 65 | 56 |
| 1 | 86 | 3 | 545898 | 900193 | 51 | 59 |
| 1 | 87 | 1 | 545901 | 900197 | 55 | 54 |
| 1 | 87 | 2 | 545904 | 900209 | 60 | 59 |
| 1 | 87 | 3 | 545910 | 900222 | 59 | 53 |
| 1 | 88 | 1 | 545908 | 900228 | 53 | 56 |
| 1 | 88 | 2 | 545907 | 900240 | 58 | 57 |
| 1 | 88 | 3 | 545916 | 900252 | 40 | 39 |
| 1 | 89 | 1 | 545919 | 900254 | 60 | 55 |
| 1 | 89 | 2 | 545925 | 900262 | 66 | 61 |
| 1 | 89 | 3 | 545930 | 900275 | 65 | 60 |
| 1 | 90 | 1 | 545931 | 900284 | 64 | 58 |
| 1 | 90 | 2 | 545932 | 900290 | 69 | 61 |
| 1 | 90 | 3 | 545934 | 900298 | 63 | 59 |
| 1 | 91 | 1 | 545973 | 900289 | 64 | 73 |
| 1 | 91 | 2 | 545970 | 900280 | 46 | 53 |
| 1 | 91 | 3 | 545967 | 900271 | 54 | 56 |
| 1 | 92 | 1 | 545967 | 900266 | 60 | 61 |
| 1 | 92 | 2 | 545963 | 900256 | 71 | 65 |
| 1 | 92 | 3 | 545958 | 900240 | 90 | 73 |
| 1 | 93 | 1 | 545955 | 900233 | 82 | 71 |
| 1 | 93 | 2 | 545958 | 900224 | 70 | 64 |
| 1 | 93 | 3 | 545955 | 900208 | 62 | 57 |
| 1 | 94 | 1 | 545952 | 900204 | 62 | 59 |
| 1 | 94 | 2 | 545946 | 900197 | 55 | 56 |
| 1 | 94 | 3 | 545944 | 900183 | 57 | 48 |
| 1 | 95 | 1 | 545942 | 900178 | 58 | 59 |
| 1 | 95 | 2 | 545941 | 900172 | 57 | 58 |
| 1 | 95 | 3 | 545934 | 900159 | 47 | 58 |
| 1 | 96 | 1 | 545968 | 900139 | 61 | 63 |
| 1 | 96 | 2 | 545976 | 900147 | 61 | 64 |
| 1 | 96 | 3 | 545986 | 900158 | 57 | 63 |

|   |     |   |        |        |    |    |
|---|-----|---|--------|--------|----|----|
| 1 | 97  | 1 | 545986 | 900161 | 78 | 71 |
| 1 | 97  | 2 | 545992 | 900172 | 79 | 64 |
| 1 | 97  | 3 | 546001 | 900189 | 60 | 59 |
| 1 | 98  | 1 | 546001 | 900193 | 65 | 60 |
| 1 | 98  | 2 | 546003 | 900200 | 59 | 57 |
| 1 | 98  | 3 | 546007 | 900210 | 52 | 54 |
| 1 | 99  | 1 | 545009 | 900215 | 59 | 58 |
| 1 | 99  | 2 | 545010 | 900227 | 59 | 62 |
| 1 | 99  | 3 | 545016 | 900243 | 70 | 67 |
| 1 | 100 | 1 | 545019 | 900249 | 82 | 73 |
| 1 | 100 | 2 | 545019 | 900259 | 81 | 68 |
| 1 | 100 | 3 | 545021 | 900271 | 79 | 72 |

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 5      | 1      | 1     | 547034 | 899404 | 261      | 194        |
| 5      | 1      | 2     | 547037 | 899395 | 228      | 180        |
| 5      | 1      | 3     | 547037 | 899388 | 209      | 152        |
| 5      | 2      | 1     | 547040 | 899384 | 202      | 139        |

|   |    |   |        |        |     |     |
|---|----|---|--------|--------|-----|-----|
| 5 | 2  | 2 | 547045 | 899374 | 224 | 183 |
| 5 | 2  | 3 | 547051 | 899347 | 188 | 141 |
| 5 | 3  | 1 | 547051 | 899338 | 167 | 129 |
| 5 | 3  | 2 | 547053 | 899321 | 171 | 133 |
| 5 | 3  | 3 | 547060 | 899301 | 200 | 146 |
| 5 | 4  | 1 | 547064 | 899291 | 180 | 130 |
| 5 | 4  | 2 | 547063 | 899277 | 161 | 121 |
| 5 | 4  | 3 | 547067 | 899249 | 210 | 153 |
| 5 | 5  | 1 | 547073 | 899244 | 220 | 166 |
| 5 | 5  | 2 | 547076 | 899227 | 208 | 163 |
| 5 | 5  | 3 | 547084 | 899206 | 178 | 141 |
| 5 | 6  | 1 | 547085 | 899201 | 160 | 119 |
| 5 | 6  | 2 | 547090 | 899189 | 130 | 104 |
| 5 | 6  | 3 | 547098 | 899163 | 128 | 100 |
| 5 | 7  | 1 | 547098 | 899153 | 134 | 106 |
| 5 | 7  | 2 | 547100 | 899132 | 136 | 120 |
| 5 | 7  | 3 | 547106 | 899115 | 111 | 80  |
| 5 | 8  | 1 | 547105 | 899109 | 101 | 90  |
| 5 | 8  | 2 | 547110 | 899091 | 94  | 80  |
| 5 | 8  | 3 | 547113 | 899073 | 80  | 61  |
| 5 | 9  | 1 | 547115 | 899062 | 78  | 71  |
| 5 | 9  | 2 | 547121 | 899041 | 79  | 72  |
| 5 | 9  | 3 | 547124 | 899020 | 67  | 69  |
| 5 | 10 | 1 | 547130 | 899008 | 67  | 64  |
| 5 | 10 | 2 | 547129 | 898989 | 63  | 63  |
| 5 | 10 | 3 | 547140 | 898977 | 80  | 71  |
| 5 | 11 | 1 | 547141 | 898968 | 51  | 54  |
| 5 | 11 | 2 | 547140 | 898945 | 60  | 59  |
| 5 | 11 | 3 | 547151 | 898923 | 62  | 62  |
| 5 | 12 | 1 | 547125 | 898899 | 56  | 57  |
| 5 | 12 | 2 | 547119 | 898924 | 57  | 58  |
| 5 | 12 | 3 | 547121 | 898942 | 54  | 53  |
| 5 | 13 | 1 | 547121 | 899951 | 63  | 64  |
| 5 | 13 | 2 | 547118 | 898970 | 62  | 73  |
| 5 | 13 | 3 | 547115 | 898996 | 62  | 60  |
| 5 | 14 | 1 | 547112 | 899002 | 68  | 71  |
| 5 | 14 | 2 | 547100 | 899020 | 64  | 64  |
| 5 | 14 | 3 | 547099 | 899035 | 75  | 65  |
| 5 | 15 | 1 | 547094 | 899045 | 81  | 68  |
| 5 | 15 | 2 | 547088 | 899061 | 93  | 76  |
| 5 | 15 | 3 | 547092 | 899084 | 90  | 73  |
| 5 | 16 | 1 | 547085 | 899096 | 92  | 74  |
| 5 | 16 | 2 | 547079 | 899112 | 74  | 64  |
| 5 | 16 | 3 | 547074 | 899128 | 73  | 66  |
| 5 | 17 | 1 | 547072 | 899166 | 79  | 70  |
| 5 | 17 | 2 | 547069 | 899151 | 110 | 92  |
| 5 | 17 | 3 | 547060 | 899171 | 117 | 89  |

|   |    |   |        |         |     |     |
|---|----|---|--------|---------|-----|-----|
| 5 | 18 | 1 | 547059 | 899184  | 140 | 101 |
| 5 | 18 | 2 | 547057 | 899204  | 147 | 116 |
| 5 | 18 | 3 | 547052 | 899222  | 144 | 107 |
| 5 | 19 | 1 | 547050 | 899227  | 152 | 112 |
| 5 | 19 | 2 | 547045 | 899244  | 172 | 122 |
| 5 | 19 | 3 | 547045 | 899273  | 176 | 138 |
| 5 | 20 | 1 | 547042 | 899279  | 212 | 158 |
| 5 | 20 | 2 | 547034 | 899296  | 219 | 170 |
| 5 | 20 | 3 | 547029 | 899310  | 150 | 119 |
| 5 | 21 | 1 | 547029 | 899618  | 152 | 113 |
| 5 | 21 | 2 | 547025 | 899640  | 142 | 106 |
| 5 | 21 | 3 | 547021 | 899361  | 112 | 87  |
| 5 | 22 | 1 | 547017 | 899369  | 122 | 89  |
| 5 | 22 | 2 | 547011 | 899390  | 132 | 103 |
| 5 | 22 | 3 | 547001 | 899406  | 147 | 118 |
| 5 | 23 | 1 | 546988 | 899380  | 77  | 65  |
| 5 | 23 | 2 | 547001 | 899368  | 90  | 74  |
| 5 | 23 | 3 | 547000 | 899345  | 97  | 71  |
| 5 | 24 | 1 | 547002 | 899343  | 119 | 89  |
| 5 | 24 | 2 | 547005 | 899323  | 123 | 92  |
| 5 | 24 | 3 | 547014 | 899301  | 125 | 91  |
| 5 | 25 | 1 | 57020  | 899250  | 135 | 106 |
| 5 | 25 | 2 | 547021 | 899271  | 138 | 100 |
| 5 | 25 | 3 | 547033 | 899263  | 124 | 97  |
| 5 | 26 | 1 | 547027 | 899250  | 131 | 90  |
| 5 | 26 | 2 | 547032 | 899226  | 164 | 118 |
| 5 | 26 | 3 | 547031 | 899204  | 99  | 74  |
| 5 | 27 | 1 | 547036 | 899204  | 98  | 77  |
| 5 | 27 | 2 | 547044 | 899174  | 73  | 66  |
| 5 | 27 | 3 | 547042 | 899160  | 73  | 65  |
| 5 | 28 | 1 | 547047 | 899152  | 72  | 70  |
| 5 | 28 | 2 | 547053 | 899136  | 66  | 59  |
| 5 | 28 | 3 | 547057 | 899120  | 60  | 51  |
| 5 | 29 | 1 | 547062 | 899114  | 60  | 55  |
| 5 | 29 | 2 | 547064 | 899094  | 64  | 56  |
| 5 | 29 | 3 | 547068 | 899074  | 80  | 60  |
| 5 | 30 | 1 | 547068 | 899063  | 78  | 54  |
| 5 | 30 | 2 | 547073 | 899042  | 72  | 60  |
| 5 | 30 | 3 | 547078 | 899022  | 58  | 59  |
| 5 | 31 | 1 | 547080 | 899016  | 59  | 54  |
| 5 | 31 | 2 | 547087 | 899000  | 61  | 52  |
| 5 | 31 | 3 | 547088 | 8998975 | 60  | 62  |
| 5 | 32 | 1 | 547091 | 898967  | 62  | 60  |
| 5 | 32 | 2 | 547094 | 898948  | 60  | 58  |
| 5 | 32 | 3 | 547100 | 898937  | 66  | 62  |
| 5 | 33 | 1 | 547101 | 898923  | 52  | 55  |
| 5 | 33 | 2 | 547107 | 898903  | 55  | 60  |

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|---|----|---|--------|--------|-----|-----|
| 5 | 33 | 3 | 547111 | 898893 | 56  | 55  |
| 5 | 34 | 1 | 547084 | 898873 | 60  | 54  |
| 5 | 34 | 2 | 547079 | 898891 | 62  | 60  |
| 5 | 34 | 3 | 547085 | 898901 | 56  | 58  |
| 5 | 35 | 1 | 547084 | 898906 | 59  | 60  |
| 5 | 35 | 2 | 547076 | 898916 | 67  | 71  |
| 5 | 35 | 3 | 547070 | 898941 | 62  | 56  |
| 5 | 36 | 1 | 547068 | 898948 | 60  | 57  |
| 5 | 36 | 2 | 547065 | 898967 | 62  | 62  |
| 5 | 36 | 3 | 547063 | 898993 | 55  | 59  |
| 5 | 37 | 1 | 547058 | 898999 | 61  | 53  |
| 5 | 37 | 2 | 547057 | 899014 | 56  | 52  |
| 5 | 37 | 3 | 547049 | 899036 | 59  | 51  |
| 5 | 38 | 1 | 547045 | 899045 | 65  | 57  |
| 5 | 38 | 2 | 547041 | 899066 | 67  | 64  |
| 5 | 38 | 3 | 547042 | 899091 | 66  | 63  |
| 5 | 39 | 1 | 547037 | 899096 | 93  | 67  |
| 5 | 39 | 2 | 547030 | 899108 | 97  | 79  |
| 5 | 39 | 3 | 547025 | 899131 | 89  | 72  |
| 5 | 40 | 1 | 547024 | 899136 | 69  | 63  |
| 5 | 40 | 2 | 547020 | 899153 | 73  | 63  |
| 5 | 40 | 3 | 547014 | 899177 | 70  | 60  |
| 5 | 41 | 1 | 547012 | 899184 | 65  | 54  |
| 5 | 41 | 2 | 547008 | 899199 | 73  | 65  |
| 5 | 41 | 3 | 547002 | 899221 | 64  | 60  |
| 5 | 42 | 1 | 546997 | 899227 | 65  | 61  |
| 5 | 42 | 2 | 546998 | 899241 | 83  | 75  |
| 5 | 42 | 3 | 546991 | 899269 | 74  | 62  |
| 5 | 43 | 1 | 546987 | 899272 | 68  | 62  |
| 5 | 43 | 2 | 546984 | 899295 | 79  | 74  |
| 5 | 43 | 3 | 546981 | 899317 | 79  | 63  |
| 5 | 44 | 1 | 546980 | 899342 | 85  | 69  |
| 5 | 44 | 2 | 546978 | 899335 | 119 | 94  |
| 5 | 44 | 3 | 546975 | 899344 | 135 | 101 |
| 5 | 45 | 1 | 546956 | 899293 | 61  | 55  |
| 5 | 45 | 2 | 546963 | 899275 | 69  | 67  |
| 5 | 45 | 3 | 546969 | 899258 | 61  | 59  |
| 5 | 46 | 1 | 546973 | 899253 | 58  | 53  |
| 5 | 46 | 2 | 546979 | 899235 | 72  | 60  |
| 5 | 46 | 3 | 546985 | 899216 | 60  | 59  |
| 5 | 47 | 1 | 546983 | 899207 | 62  | 55  |
| 5 | 47 | 2 | 546985 | 899189 | 72  | 69  |
| 5 | 47 | 3 | 546993 | 899169 | 61  | 52  |
| 5 | 48 | 1 | 546996 | 899160 | 63  | 54  |
| 5 | 48 | 2 | 546999 | 899141 | 64  | 72  |
| 5 | 48 | 3 | 547006 | 899110 | 96  | 71  |
| 5 | 49 | 1 | 547011 | 899111 | 102 | 77  |

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|---|----|---|--------|--------|-----|----|
| 5 | 49 | 2 | 547012 | 899094 | 88  | 69 |
| 5 | 49 | 3 | 547015 | 899069 | 76  | 62 |
| 5 | 50 | 1 | 547017 | 899066 | 64  | 57 |
| 5 | 50 | 2 | 547018 | 899045 | 64  | 55 |
| 5 | 50 | 3 | 547029 | 899028 | 52  | 48 |
| 5 | 51 | 1 | 547032 | 899023 | 53  | 50 |
| 5 | 51 | 2 | 547035 | 898002 | 59  | 58 |
| 5 | 51 | 3 | 547037 | 898002 | 60  | 60 |
| 5 | 52 | 1 | 547037 | 898967 | 57  | 59 |
| 5 | 52 | 2 | 547045 | 898950 | 59  | 58 |
| 5 | 52 | 3 | 547052 | 898937 | 59  | 56 |
| 5 | 53 | 1 | 547052 | 898922 | 61  | 50 |
| 5 | 53 | 2 | 547057 | 898900 | 65  | 64 |
| 5 | 53 | 3 | 547061 | 898882 | 61  | 57 |
| 5 | 54 | 1 | 547064 | 898877 | 59  | 61 |
| 5 | 54 | 2 | 547067 | 898862 | 58  | 55 |
| 5 | 54 | 3 | 547066 | 898856 | 49  | 47 |
| 5 | 55 | 1 | 546932 | 898269 | 92  | 74 |
| 5 | 55 | 2 | 546936 | 898263 | 102 | 82 |
| 5 | 55 | 3 | 546947 | 898247 | 103 | 80 |
| 5 | 56 | 1 | 546953 | 898238 | 117 | 86 |
| 5 | 56 | 2 | 546958 | 898227 | 113 | 93 |
| 5 | 56 | 3 | 546964 | 898200 | 100 | 76 |
| 5 | 57 | 1 | 546962 | 898193 | 103 | 86 |
| 5 | 57 | 2 | 546966 | 898179 | 84  | 73 |
| 5 | 57 | 3 | 546967 | 898162 | 98  | 78 |
| 5 | 58 | 1 | 546973 | 898150 | 91  | 78 |
| 5 | 58 | 2 | 546984 | 898125 | 98  | 80 |
| 5 | 58 | 3 | 546987 | 898091 | 97  | 81 |
| 5 | 59 | 1 | 546977 | 898080 | 89  | 69 |
| 5 | 59 | 2 | 546981 | 898059 | 83  | 73 |
| 5 | 59 | 3 | 546988 | 898046 | 71  | 62 |
| 5 | 60 | 1 | 546992 | 898042 | 79  | 66 |
| 5 | 60 | 2 | 546997 | 898026 | 66  | 60 |
| 5 | 60 | 3 | 547000 | 898003 | 65  | 66 |
| 5 | 61 | 1 | 547003 | 898995 | 61  | 54 |
| 5 | 61 | 2 | 547009 | 898978 | 53  | 54 |
| 5 | 61 | 3 | 547010 | 898969 | 65  | 60 |
| 5 | 62 | 1 | 547015 | 898957 | 62  | 58 |
| 5 | 62 | 2 | 547019 | 898942 | 49  | 44 |
| 5 | 62 | 3 | 547022 | 898919 | 53  | 53 |
| 5 | 63 | 1 | 547029 | 898912 | 47  | 42 |
| 5 | 63 | 2 | 547037 | 898889 | 59  | 53 |
| 5 | 63 | 3 | 547036 | 898868 | 55  | 53 |
| 5 | 64 | 1 | 547038 | 898863 | 65  | 61 |
| 5 | 64 | 2 | 547042 | 898857 | 62  | 57 |
| 5 | 65 | 1 | 546973 | 899097 | 80  | 75 |

|   |    |   |        |        |     |     |
|---|----|---|--------|--------|-----|-----|
| 5 | 65 | 2 | 546968 | 899120 | 75  | 64  |
| 5 | 65 | 3 | 546964 | 899129 | 76  | 64  |
| 5 | 66 | 1 | 546961 | 899135 | 77  | 159 |
| 5 | 66 | 2 | 546949 | 899159 | 98  | 76  |
| 5 | 66 | 3 | 546943 | 899170 | 89  | 74  |
| 5 | 67 | 1 | 546938 | 899179 | 83  | 70  |
| 5 | 67 | 2 | 546939 | 899186 | 73  | 63  |
| 5 | 67 | 3 | 546933 | 899208 | 91  | 75  |
| 5 | 68 | 1 | 546932 | 899220 | 85  | 72  |
| 5 | 68 | 2 | 546917 | 899236 | 104 | 80  |
| 5 | 68 | 3 | 546910 | 899244 | 100 | 82  |

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 23     | 1      | 1     | 546314 | 901499 | 73       | 75         |
| 23     | 1      | 2     | 546324 | 901500 | 71       | 78         |
| 23     | 1      | 3     | 546333 | 901502 | 74       | 88         |
| 23     | 2      | 1     | 546352 | 901509 | 81       | 84         |
| 23     | 2      | 2     | 546360 | 901521 | 105      | 98         |
| 23     | 2      | 3     | 546367 | 901526 | 103      | 102        |
| 23     | 3      | 1     | 546389 | 901531 | 111      | 131        |
| 23     | 3      | 2     | 546397 | 901539 | 122      | 126        |
| 23     | 3      | 3     | 546409 | 901541 | 126      | 138        |
| 23     | 4      | 1     | 546424 | 901548 | 173      | 131        |
| 23     | 4      | 2     | 546435 | 901556 | 170      | 178        |
| 23     | 4      | 3     | 546446 | 901561 | 169      | 149        |
| 23     | 5      | 1     | 546463 | 901566 | 178      | 174        |
| 23     | 5      | 2     | 546472 | 901569 | 179      | 153        |
| 23     | 5      | 3     | 546488 | 901578 | 169      | 135        |
| 23     | 6      | 1     | 546498 | 901587 | 156      | 140        |
| 23     | 6      | 2     | 546521 | 901586 | 167      | 149        |
| 23     | 6      | 3     | 546530 | 901587 | 164      | 140        |
| 23     | 7      | 1     | 546546 | 901593 | 198      | 166        |
| 23     | 7      | 2     | 546554 | 901598 | 186      | 191        |
| 23     | 7      | 3     | 546566 | 901604 | 169      | 152        |
| 23     | 8      | 1     | 546576 | 901609 | 178      | 160        |
| 23     | 8      | 2     | 546588 | 901616 | 174      | 171        |
| 23     | 8      | 3     | 546601 | 901622 | 152      | 159        |
| 23     | 9      | 1     | 546614 | 901632 | 169      | 149        |
| 23     | 9      | 2     | 546627 | 901641 | 171      | 143        |
| 23     | 9      | 3     | 546642 | 901644 | 162      | 157        |
| 23     | 10     | 1     | 546649 | 901650 | 168      | 152        |
| 23     | 10     | 2     | 546657 | 901649 | 175      | 155        |
| 23     | 10     | 3     | 546665 | 901655 | 165      | 144        |
| 23     | 11     | 1     | 546649 | 901672 | 171      | 147        |
| 23     | 11     | 2     | 546641 | 901668 | 185      | 156        |
| 23     | 11     | 3     | 546632 | 901663 | 160      | 149        |
| 23     | 12     | 1     | 546618 | 901658 | 165      | 162        |



|    |    |   |        |        |     |     |
|----|----|---|--------|--------|-----|-----|
| 23 | 12 | 2 | 546605 | 901653 | 175 | 139 |
| 23 | 12 | 3 | 546591 | 901647 | 149 | 142 |
| 23 | 13 | 1 | 546584 | 901642 | 171 | 156 |
| 23 | 13 | 2 | 546575 | 901637 | 163 | 156 |
| 23 | 13 | 3 | 546557 | 901629 | 175 | 149 |
| 23 | 14 | 1 | 546542 | 901627 | 171 | 147 |
| 23 | 14 | 2 | 546533 | 901621 | 162 | 147 |
| 23 | 14 | 3 | 546520 | 901614 | 160 | 132 |
| 23 | 15 | 1 | 546505 | 901611 | 172 | 150 |
| 23 | 15 | 2 | 546492 | 901607 | 147 | 125 |
| 23 | 15 | 3 | 546479 | 901599 | 170 | 154 |
| 23 | 16 | 1 | 546469 | 901593 | 147 | 123 |
| 23 | 16 | 2 | 546454 | 901589 | 176 | 138 |
| 23 | 16 | 3 | 546433 | 901579 | 138 | 115 |
| 23 | 17 | 1 | 546427 | 901575 | 156 | 132 |
| 23 | 17 | 2 | 546413 | 901567 | 172 | 149 |
| 23 | 17 | 3 | 546398 | 901562 | 168 | 173 |
| 23 | 18 | 1 | 546393 | 901556 | 150 | 177 |
| 23 | 18 | 2 | 546377 | 901549 | 122 | 139 |
| 23 | 18 | 3 | 546361 | 901544 | 115 | 115 |
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| 23 | 19 | 2 | 546344 | 901531 | 82  | 84  |
| 23 | 19 | 3 | 546323 | 901527 | 181 | 177 |
| 23 | 20 | 1 | 546313 | 901522 | 74  | 84  |
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| 23 | 21 | 1 | 546267 | 901533 | 59  | 68  |
| 23 | 21 | 2 | 546287 | 901542 | 114 | 120 |
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| 23 | 22 | 2 | 546317 | 901562 | 145 | 163 |
| 23 | 22 | 3 | 546328 | 901570 | 142 | 170 |
| 23 | 23 | 1 | 546341 | 901575 | 141 | 126 |
| 23 | 23 | 2 | 546355 | 901580 | 160 | 136 |
| 23 | 23 | 3 | 546363 | 901587 | 127 | 106 |
| 23 | 24 | 1 | 546377 | 901580 | 142 | 111 |
| 23 | 24 | 2 | 546386 | 901594 | 141 | 117 |
| 23 | 24 | 3 | 546405 | 901602 | 165 | 142 |
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| 23 | 25 | 2 | 546427 | 901610 | 187 | 170 |
| 23 | 25 | 3 | 546442 | 901618 | 160 | 143 |
| 23 | 26 | 1 | 546454 | 901622 | 161 | 145 |
| 23 | 26 | 2 | 546469 | 901626 | 141 | 130 |
| 23 | 26 | 3 | 546482 | 901635 | 132 | 115 |
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| 23 | 29 | 2 | 546587 | 901667 | 155 | 129 |
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| 23 | 30 | 1 | 546606 | 901689 | 146 | 113 |
| 23 | 30 | 2 | 546615 | 901696 | 138 | 123 |
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| 23 | 31 | 2 | 546593 | 901710 | 147 | 123 |
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| 23 | 33 | 2 | 546524 | 901682 | 147 | 137 |
| 23 | 33 | 3 | 546514 | 901674 | 137 | 139 |
| 23 | 34 | 1 | 546463 | 901549 | 154 | 137 |
| 23 | 34 | 2 | 546448 | 901641 | 138 | 138 |
| 23 | 34 | 3 | 546433 | 901639 | 144 | 148 |
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| 23 | 35 | 2 | 546490 | 901661 | 154 | 143 |
| 23 | 35 | 3 | 546474 | 901656 | 144 | 145 |
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| 23 | 38 | 1 | 546348 | 901601 | 131 | 105 |
| 23 | 38 | 2 | 546334 | 901597 | 150 | 121 |
| 23 | 38 | 3 | 546320 | 901592 | 122 | 104 |
| 23 | 39 | 1 | 546311 | 901582 | 118 | 97  |
| 23 | 39 | 2 | 546297 | 901583 | 141 | 127 |
| 23 | 39 | 3 | 546279 | 901576 | 153 | 138 |
| 23 | 40 | 1 | 546272 | 901569 | 170 | 160 |
| 23 | 40 | 2 | 546256 | 901558 | 177 | 158 |
| 23 | 40 | 3 | 546250 | 901554 | 143 | 125 |
| 23 | 41 | 1 | 546223 | 901579 | 131 | 114 |
| 23 | 41 | 2 | 546239 | 901590 | 117 | 105 |
| 23 | 41 | 3 | 546246 | 901595 | 109 | 103 |
| 23 | 42 | 1 | 546259 | 901596 | 93  | 88  |
| 23 | 42 | 2 | 546272 | 901600 | 101 | 97  |
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| 23 | 43 | 1 | 546300 | 901610 | 108 | 94  |
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| 23 | 44 | 3 | 546366 | 901641 | 154 | 133 |
| 23 | 45 | 1 | 546377 | 901647 | 112 | 97  |
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| 23 | 46 | 3 | 546449 | 901668 | 135 | 112 |
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| 23 | 47 | 2 | 546460 | 901688 | 119 | 108 |
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| 23 | 48 | 2 | 546499 | 901707 | 102 | 102 |
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| 23 | 49 | 1 | 546520 | 901718 | 106 | 88  |
| 23 | 49 | 2 | 546539 | 901725 | 108 | 111 |
| 23 | 49 | 3 | 546555 | 901730 | 106 | 98  |
| 23 | 50 | 1 | 546561 | 901735 | 108 | 97  |
| 23 | 50 | 2 | 546572 | 901733 | 121 | 110 |
| 23 | 50 | 3 | 546581 | 901739 | 110 | 113 |
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| 23 | 53 | 1 | 546502 | 901731 | 90  | 84  |
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| 23 | 54 | 2 | 546447 | 901710 | 105 | 95  |
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| 23 | 55 | 1 | 546420 | 901700 | 83  | 83  |
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| 23 | 56 | 2 | 546376 | 901674 | 115 | 90  |
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| 23 | 57 | 1 | 546349 | 901661 | 111 | 95  |
| 23 | 57 | 2 | 546335 | 901658 | 110 | 93  |
| 23 | 57 | 3 | 546315 | 901651 | 143 | 123 |
| 23 | 58 | 1 | 546308 | 901650 | 142 | 135 |
| 23 | 58 | 2 | 546393 | 901643 | 136 | 124 |
| 23 | 58 | 3 | 546274 | 901637 | 121 | 99  |
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| 23 | 60 | 3 | 546203 | 901603 | 85  | 95  |
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| 23 | 62 | 2 | 546230 | 901640 | 104 | 96  |
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| 23 | 63 | 2 | 546249 | 901662 | 101 | 101 |
| 23 | 63 | 3 | 546286 | 901665 | 88  | 88  |
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| 23 | 64 | 2 | 546308 | 901685 | 91  | 80  |
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| 23 | 65 | 2 | 546347 | 901696 | 106 | 95  |
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| 23 | 66 | 1 | 546361 | 901705 | 81  | 73  |
| 23 | 66 | 2 | 546385 | 901713 | 79  | 83  |
| 23 | 66 | 3 | 546402 | 901715 | 76  | 79  |
| 23 | 67 | 1 | 546408 | 901718 | 74  | 73  |
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| 23 | 67 | 3 | 546444 | 901733 | 94  | 96  |
| 23 | 68 | 1 | 546445 | 901739 | 88  | 82  |
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| 23 | 69 | 1 | 546483 | 901760 | 92  | 87  |
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| 23 | 73 | 3 | 546428 | 901774 | 75  | 84  |
| 23 | 74 | 1 | 546420 | 901759 | 84  | 79  |
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| 23 | 74 | 3 | 546327 | 901745 | 76  | 71  |

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| 23 | 75 | 2 | 546366 | 901734 | 73  | 91  |
| 23 | 75 | 3 | 546349 | 901726 | 65  | 85  |
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| 23 | 76 | 2 | 546320 | 901714 | 87  | 92  |
| 23 | 76 | 3 | 546310 | 901710 | 85  | 90  |
| 23 | 77 | 1 | 546302 | 901708 | 73  | 82  |
| 23 | 77 | 2 | 546290 | 901702 | 76  | 75  |
| 23 | 77 | 3 | 546273 | 901693 | 85  | 86  |
| 23 | 78 | 1 | 546265 | 901686 | 96  | 99  |
| 23 | 78 | 2 | 546250 | 901680 | 117 | 114 |
| 23 | 78 | 3 | 546235 | 901675 | 93  | 93  |
| 23 | 79 | 1 | 546227 | 901681 | 92  | 87  |
| 23 | 79 | 2 | 546210 | 901666 | 111 | 105 |
| 23 | 79 | 3 | 546195 | 901691 | 100 | 93  |
| 23 | 80 | 1 | 546190 | 901657 | 130 | 118 |
| 23 | 80 | 2 | 546170 | 901650 | 162 | 138 |
| 23 | 80 | 3 | 546157 | 901644 | 164 | 142 |
| 23 | 81 | 1 | 546139 | 901662 | 161 | 130 |
| 23 | 81 | 2 | 546153 | 901669 | 116 | 110 |
| 23 | 81 | 3 | 546167 | 901675 | 105 | 95  |
| 23 | 82 | 1 | 546178 | 901680 | 103 | 94  |
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| 23 | 83 | 1 | 546213 | 901694 | 46  | 55  |
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| 23 | 85 | 3 | 546320 | 901745 | 70  | 73  |
| 23 | 86 | 1 | 546327 | 901752 | 73  | 72  |
| 23 | 86 | 2 | 546348 | 901757 | 76  | 74  |
| 23 | 86 | 3 | 546356 | 901771 | 73  | 73  |
| 23 | 87 | 1 | 546374 | 901777 | 73  | 72  |
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| 23 | 88 | 2 | 546417 | 901789 | 86  | 84  |
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| 23 | 89 | 1 | 546444 | 901801 | 89  | 80  |
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| 23 | 90 | 1 | 546477 | 901820 | 78  | 75  |
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| 23 | 91  | 2 | 546486 | 901842 | 105 | 97  |
| 23 | 91  | 3 | 546472 | 901840 | 77  | 85  |
| 23 | 92  | 1 | 546453 | 901837 | 83  | 76  |
| 23 | 92  | 2 | 546440 | 901830 | 77  | 79  |
| 23 | 92  | 3 | 546424 | 901822 | 73  | 72  |
| 23 | 93  | 1 | 546416 | 901816 | 83  | 79  |
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| 23 | 93  | 3 | 546386 | 901801 | 72  | 68  |
| 23 | 94  | 1 | 546372 | 901881 | 88  | 92  |
| 23 | 94  | 2 | 546361 | 901794 | 77  | 76  |
| 23 | 94  | 3 | 546347 | 901788 | 70  | 79  |
| 23 | 95  | 1 | 546335 | 901784 | 71  | 77  |
| 23 | 95  | 2 | 546323 | 901776 | 65  | 72  |
| 23 | 95  | 3 | 546310 | 901778 | 56  | 58  |
| 23 | 96  | 1 | 546304 | 901773 | 64  | 62  |
| 23 | 96  | 2 | 546288 | 901758 | 68  | 69  |
| 23 | 96  | 3 | 546271 | 901752 | 63  | 57  |
| 23 | 97  | 1 | 546273 | 901747 | 58  | 60  |
| 23 | 97  | 2 | 546250 | 901741 | 71  | 77  |
| 23 | 97  | 3 | 546233 | 901737 | 63  | 70  |
| 23 | 98  | 1 | 546227 | 901733 | 36  | 48  |
| 23 | 98  | 2 | 546209 | 901722 | 36  | 45  |
| 23 | 98  | 3 | 546193 | 901720 | 47  | 54  |
| 23 | 99  | 1 | 546187 | 901713 | 53  | 57  |
| 23 | 99  | 2 | 546175 | 901707 | 58  | 75  |
| 23 | 99  | 3 | 546159 | 901701 | 85  | 78  |
| 23 | 100 | 1 | 546149 | 901696 | 95  | 57  |
| 23 | 100 | 2 | 546136 | 901688 | 112 | 95  |
| 23 | 100 | 3 | 546121 | 901683 | 127 | 107 |
| 23 | 101 | 1 | 546100 | 901706 | 75  | 75  |
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| 23 | 101 | 3 | 546126 | 901722 | 53  | 70  |
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| 23 | 102 | 2 | 546151 | 901734 | 100 | 92  |
| 23 | 102 | 3 | 546165 | 901739 | 105 | 94  |
| 23 | 103 | 1 | 546174 | 901744 | 103 | 183 |
| 23 | 103 | 2 | 546186 | 901749 | 113 | 101 |
| 23 | 103 | 3 | 546202 | 901758 | 108 | 97  |
| 23 | 104 | 1 | 546210 | 901773 | 115 | 103 |
| 23 | 104 | 2 | 546223 | 901775 | 101 | 94  |
| 23 | 104 | 3 | 546238 | 901775 | 117 | 107 |
| 23 | 105 | 1 | 546244 | 901780 | 130 | 112 |
| 23 | 105 | 2 | 546259 | 901784 | 125 | 108 |
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| 23 | 106 | 1 | 546285 | 901796 | 101 | 87  |

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| 23 | 107 | 3 | 546350 | 901828 | 124 | 115 |
| 23 | 108 | 1 | 546374 | 901830 | 118 | 109 |
| 23 | 108 | 2 | 546376 | 901834 | 135 | 120 |
| 23 | 108 | 3 | 546392 | 901840 | 119 | 104 |
| 23 | 109 | 1 | 546398 | 901845 | 125 | 104 |
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| 23 | 114 | 2 | 546324 | 901842 | 124 | 104 |
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| 23 | 115 | 2 | 546288 | 901822 | 116 | 99  |
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| 23 | 116 | 3 | 546232 | 901795 | 130 | 107 |
| 23 | 117 | 1 | 546222 | 901794 | 140 | 117 |
| 23 | 117 | 2 | 546207 | 901785 | 140 | 117 |
| 23 | 117 | 3 | 546192 | 901780 | 130 | 113 |
| 23 | 118 | 1 | 546184 | 901776 | 137 | 103 |
| 23 | 118 | 2 | 546178 | 901779 | 127 | 107 |
| 23 | 118 | 3 | 546151 | 901770 | 101 | 87  |
| 23 | 119 | 1 | 546152 | 901756 | 92  | 87  |
| 23 | 119 | 2 | 546137 | 901755 | 94  | 96  |
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| 23 | 131 | 5 | 546376 | 901927 | 346 | 253 |
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| 23 | 132 | 2 | 546356 | 901920 | 280 | 197 |
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| 23 | 139 | 2 | 546095 | 901798 | 133 | 106  |
| 23 | 139 | 3 | 546076 | 901790 | 153 | 126  |
| 23 | 140 | 1 | 546070 | 901784 | 157 | 119  |
| 23 | 140 | 2 | 546053 | 901775 | 143 | 115  |
| 23 | 140 | 3 | 546043 | 901766 | 119 | 100  |
| 23 | 141 | 1 | 546022 | 901791 | 100 | 81   |
| 23 | 141 | 2 | 546034 | 901805 | 152 | 123  |
| 23 | 141 | 3 | 546042 | 901809 | 117 | 105  |
| 23 | 142 | 1 | 546049 | 901811 | 134 | 108  |
| 23 | 142 | 2 | 546061 | 901815 | 164 | 139  |
| 23 | 142 | 3 | 546078 | 901826 | 166 | 119  |
| 23 | 143 | 1 | 546083 | 901829 | 163 | 123  |
| 23 | 143 | 2 | 546105 | 901834 | 155 | 1120 |
| 23 | 143 | 3 | 546122 | 901840 | 135 | 114  |
| 23 | 144 | 1 | 546127 | 901842 | 121 | 97   |
| 23 | 144 | 2 | 546138 | 901848 | 127 | 173  |
| 23 | 144 | 3 | 546161 | 901855 | 162 | 122  |
| 23 | 145 | 1 | 546165 | 901859 | 169 | 123  |
| 23 | 145 | 2 | 546181 | 901868 | 159 | 124  |
| 23 | 145 | 3 | 546194 | 901874 | 145 | 114  |
| 23 | 146 | 1 | 546199 | 901878 | 140 | 117  |
| 23 | 146 | 2 | 546216 | 901880 | 171 | 136  |
| 23 | 146 | 3 | 546234 | 901890 | 151 | 109  |
| 23 | 147 | 1 | 546234 | 901895 | 115 | 93   |
| 23 | 147 | 2 | 546258 | 901903 | 68  | 73   |
| 23 | 147 | 3 | 546268 | 901912 | 118 | 95   |
| 23 | 148 | 1 | 546276 | 901917 | 154 | 117  |
| 23 | 148 | 2 | 546292 | 901925 | 268 | 203  |
| 23 | 148 | 3 | 546299 | 901931 | 275 | 207  |
| 23 | 149 | 1 | 546258 | 901928 | 116 | 97   |
| 23 | 149 | 2 | 546239 | 901924 | 115 | 96   |
| 23 | 149 | 3 | 546225 | 901917 | 105 | 83   |
| 23 | 150 | 1 | 546216 | 901912 | 119 | 94   |
| 23 | 150 | 2 | 546202 | 901909 | 136 | 106  |
| 23 | 150 | 3 | 546185 | 901898 | 140 | 116  |
| 23 | 151 | 1 | 546179 | 901893 | 144 | 111  |
| 23 | 151 | 2 | 546164 | 901887 | 174 | 143  |

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| 23 | 151 | 3 | 546148 | 901879 | 146 | 117 |
| 23 | 152 | 1 | 546141 | 901877 | 132 | 104 |
| 23 | 152 | 2 | 546125 | 901873 | 145 | 114 |
| 23 | 152 | 3 | 546107 | 901865 | 146 | 113 |
| 23 | 153 | 1 | 546100 | 901865 | 174 | 124 |
| 23 | 153 | 2 | 546084 | 901856 | 180 | 132 |
| 23 | 153 | 3 | 546070 | 901849 | 132 | 107 |
| 23 | 154 | 1 | 546064 | 901847 | 144 | 109 |
| 23 | 154 | 2 | 546052 | 901841 | 117 | 95  |
| 23 | 154 | 3 | 546032 | 901829 | 117 | 93  |
| 23 | 155 | 1 | 546028 | 901824 | 134 | 100 |
| 23 | 155 | 2 | 546016 | 901821 | 130 | 104 |
| 23 | 155 | 3 | 546000 | 901818 | 94  | 75  |
| 23 | 156 | 1 | 545975 | 901833 | 82  | 70  |
| 23 | 156 | 2 | 545985 | 901842 |     | 80  |
| 23 | 156 | 3 | 546000 | 901852 |     | 89  |
| 23 | 157 | 1 | 546006 | 901856 | 106 | 88  |
| 23 | 157 | 2 | 546015 | 901860 | 108 | 89  |
| 23 | 157 | 3 | 546036 | 901867 | 96  | 80  |
| 23 | 158 | 1 | 546043 | 901871 | 90  | 78  |
| 23 | 158 | 2 | 546062 | 901875 | 146 | 110 |
| 23 | 158 | 3 | 546079 | 901886 | 123 | 100 |
| 23 | 159 | 1 | 546081 | 901890 | 118 | 97  |
| 23 | 159 | 2 | 546103 | 901898 | 92  | 76  |
| 23 | 159 | 3 | 546115 | 901903 | 76  | 68  |
| 23 | 160 | 1 | 546120 | 901907 | 81  | 78  |
| 23 | 160 | 2 | 546130 | 901911 | 106 | 90  |
| 23 | 160 | 3 | 546148 | 901921 | 107 | 87  |
| 23 | 161 | 1 | 546155 | 901930 | 86  | 74  |
| 23 | 161 | 2 | 546164 | 901931 | 83  | 72  |
| 23 | 161 | 3 | 546192 | 901936 | 99  | 87  |
| 23 | 162 | 1 | 546138 | 901929 | 120 | 85  |
| 23 | 162 | 2 | 546126 | 901925 | 110 | 94  |
| 23 | 162 | 3 | 546114 | 901923 | 125 | 99  |
| 23 | 163 | 1 | 546103 | 901917 | 106 | 86  |
| 23 | 163 | 2 | 546082 | 901911 | 101 | 85  |
| 23 | 163 | 3 | 546069 | 901905 | 89  | 72  |
| 23 | 164 | 1 | 546063 | 901903 | 91  | 82  |
| 23 | 164 | 2 | 546044 | 901896 | 95  | 85  |
| 23 | 164 | 3 | 546028 | 901892 | 84  | 78  |
| 23 | 165 | 1 | 546084 | 901829 | 93  | 80  |
| 23 | 165 | 2 | 546009 | 901883 | 81  | 76  |
| 23 | 165 | 3 | 545995 | 901875 | 161 | 128 |
| 23 | 166 | 1 | 545985 | 901870 | 167 | 122 |
| 23 | 166 | 2 | 545972 | 901863 | 200 | 149 |
| 23 | 166 | 3 | 545950 | 901856 | 183 | 127 |
| 23 | 130 | 1 | 546374 | 901934 | 385 | 290 |

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| 23 | 130 | 2 | 546383 | 901939 | 405 | 344 |
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| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 32     | 1      | 1     | 545910 | 901932 | 189      | 129        |
| 32     | 1      | 2     | 545928 | 901935 | 226      | 169        |
| 32     | 1      | 3     | 545945 | 901937 | 239      | 180        |
| 32     | 2      | 1     | 545962 | 901996 | 234      | 160        |
| 32     | 2      | 2     | 545951 | 901998 | 258      | 171        |
| 32     | 2      | 3     | 545928 | 902000 | 246      | 170        |
| 32     | 3      | 1     | 545941 | 902056 | 241      | 160        |
| 32     | 3      | 2     | 545960 | 902050 | 241      | 160        |
| 32     | 3      | 3     | 545975 | 902047 | 250      | 171        |
| 32     | 4      | 1     | 545998 | 902094 | 264      | 170        |
| 32     | 4      | 2     | 545980 | 902103 | 272      | 183        |
| 32     | 4      | 3     | 545971 | 902108 | 177      | 182        |
| 32     | 5      | 1     | 545959 | 902160 | 296      | 200        |
| 32     | 5      | 2     | 545970 | 902158 | 288      | 187        |
| 32     | 5      | 3     | 545981 | 902151 | 249      | 172        |
| 32     | 6      | 1     | 545982 | 902226 | 284      | 185        |
| 32     | 6      | 2     | 545986 | 902209 | 267      | 180        |
| 32     | 6      | 3     | 545977 | 902213 | 250      | 169        |
| 32     | 7      | 1     | 545974 | 902266 | 299      | 214        |
| 32     | 7      | 2     | 545989 | 902268 | 266      | 180        |
| 32     | 7      | 3     | 546012 | 902265 | 255      | 182        |
| 32     | 8      | 1     | 546022 | 902325 | 274      | 183        |
| 32     | 8      | 2     | 546013 | 902329 | 250      | 160        |
| 32     | 8      | 3     | 545992 | 902328 | 237      | 179        |
| 32     | 9      | 1     | 545998 | 902368 | 273      | 196        |
| 32     | 9      | 2     | 546016 | 902379 | 245      | 163        |
| 32     | 9      | 3     | 546027 | 902372 | 150      | 106        |
| 32     | 10     | 1     | 546042 | 902438 | 254      | 168        |
| 32     | 10     | 2     | 546032 | 902439 | 208      | 144        |
| 32     | 10     | 3     | 546015 | 902436 | 96       | 72         |
| 32     | 11     | 1     | 546017 | 902493 | 236      | 169        |
| 32     | 11     | 2     | 546034 | 902489 | 225      | 155        |
| 32     | 11     | 3     | 546052 | 902485 | 241      | 162        |
| 32     | 12     | 1     | 546064 | 902481 | 287      | 191        |
| 32     | 12     | 2     | 546077 | 902478 | 299      | 201        |
| 32     | 12     | 3     | 546092 | 902475 | 213      | 144        |
| 32     | 13     | 1     | 546088 | 902484 | 256      | 175        |
| 32     | 13     | 2     | 546075 | 902421 | 299      | 203        |
| 32     | 13     | 3     | 546065 | 902419 | 244      | 170        |
| 32     | 14     | 1     | 546038 | 902361 | 106      | 77         |
| 32     | 14     | 2     | 546053 | 902362 | 172      | 123        |
| 32     | 14     | 3     | 546072 | 902361 | 247      | 173        |
| 32     | 15     | 1     | 546059 | 902367 | 280      | 188        |
| 32     | 15     | 2     | 546051 | 902309 | 294      | 191        |

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| 32 | 15 | 3 | 546045 | 902315 | 230 | 163 |
| 32 | 16 | 1 | 546021 | 902256 | 260 | 188 |
| 32 | 16 | 2 | 546038 | 902250 | 286 | 196 |
| 32 | 16 | 3 | 546049 | 902251 | 285 | 191 |
| 32 | 17 | 1 | 546038 | 902206 | 297 | 199 |
| 32 | 17 | 2 | 546021 | 902207 | 282 | 193 |
| 32 | 17 | 3 | 546055 | 902210 | 270 | 182 |
| 32 | 18 | 1 | 545990 | 902163 | 250 | 174 |
| 32 | 18 | 2 | 546006 | 902149 | 243 | 166 |
| 32 | 18 | 3 | 546029 | 902143 | 277 | 188 |
| 32 | 19 | 1 | 546021 | 902106 | 248 | 176 |
| 32 | 19 | 2 | 546014 | 902104 | 277 | 179 |
| 32 | 19 | 3 | 545988 | 902103 | 242 | 174 |
| 32 | 20 | 1 | 545966 | 902042 | 247 | 163 |
| 32 | 20 | 2 | 545994 | 902038 | 247 | 169 |
| 32 | 20 | 3 | 546016 | 902038 | 231 | 266 |
| 32 | 21 | 1 | 545993 | 901984 | 249 | 169 |
| 32 | 21 | 2 | 545986 | 901983 | 230 | 156 |
| 32 | 21 | 3 | 545975 | 901987 | 208 | 132 |
| 32 | 22 | 1 | 545960 | 901941 | 189 | 143 |
| 32 | 22 | 2 | 545974 | 901942 | 200 | 140 |
| 32 | 22 | 3 | 545986 | 901948 | 195 | 132 |
| 32 | 23 | 1 | 545999 | 901953 | 174 | 143 |
| 32 | 23 | 2 | 546009 | 901952 | 182 | 155 |
| 32 | 23 | 3 | 546035 | 901957 | 209 | 147 |
| 32 | 24 | 1 | 546049 | 902022 | 252 | 172 |
| 32 | 24 | 2 | 546033 | 902031 | 222 | 148 |
| 32 | 24 | 3 | 546021 | 902035 | 208 | 150 |
| 32 | 25 | 1 | 546031 | 902091 | 210 | 157 |
| 32 | 25 | 2 | 546056 | 902085 | 262 | 185 |
| 32 | 25 | 3 | 546069 | 902083 | 272 | 183 |
| 32 | 26 | 1 | 546071 | 902139 | 248 | 170 |
| 32 | 26 | 2 | 546059 | 902143 | 239 | 159 |
| 32 | 26 | 3 | 546044 | 902147 | 213 | 150 |
| 32 | 27 | 1 | 546050 | 902208 | 299 | 180 |
| 32 | 27 | 2 | 546065 | 902203 | 268 | 169 |
| 32 | 27 | 3 | 546075 | 902201 | 272 | 190 |
| 32 | 28 | 1 | 546095 | 902252 | 272 | 191 |
| 32 | 28 | 2 | 546076 | 902254 | 279 | 174 |
| 32 | 28 | 3 | 546062 | 902258 | 62  | 258 |
| 32 | 29 | 1 | 546079 | 902309 | 291 | 200 |
| 32 | 29 | 2 | 546095 | 902307 | 300 | 202 |
| 32 | 29 | 3 | 546108 | 902302 | 216 | 195 |
| 32 | 30 | 1 | 546106 | 902353 | 278 | 190 |
| 32 | 30 | 2 | 546096 | 902360 | 262 | 182 |
| 32 | 30 | 3 | 546083 | 902364 | 248 | 166 |
| 32 | 31 | 1 | 546095 | 902413 | 282 | 191 |

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| 32 | 31 | 2 | 546111 | 902419 | 298 | 195 |
| 32 | 31 | 3 | 546128 | 902419 | 284 | 202 |
| 32 | 32 | 1 | 546141 | 902488 | 225 | 147 |
| 32 | 32 | 2 | 546113 | 902495 | 136 | 92  |
| 32 | 32 | 3 | 546095 | 902281 | 218 | 141 |
| 32 | 33 | 1 | 546196 | 902459 | 271 | 193 |
| 32 | 33 | 2 | 546195 | 902471 | 115 | 90  |
| 32 | 33 | 3 | 546177 | 902468 | 175 | 122 |
| 32 | 34 | 1 | 546128 | 902413 | 225 | 153 |
| 32 | 34 | 2 | 546138 | 902419 | 88  | 64  |
| 32 | 34 | 3 | 546158 | 902415 | 239 | 151 |
| 32 | 35 | 1 | 546162 | 902365 | 247 | 168 |
| 32 | 35 | 2 | 546136 | 902361 | 146 | 114 |
| 32 | 35 | 3 | 546120 | 902358 | 242 | 153 |
| 32 | 36 | 1 | 546092 | 902297 | 248 | 163 |
| 32 | 36 | 2 | 546118 | 902303 | 158 | 116 |
| 32 | 36 | 3 | 546132 | 902302 | 145 | 110 |
| 32 | 37 | 1 | 546126 | 902247 | 248 | 166 |
| 32 | 37 | 2 | 546105 | 902244 | 255 | 167 |
| 32 | 37 | 3 | 546087 | 902245 | 270 | 189 |
| 32 | 38 | 1 | 546086 | 902181 | 141 | 162 |
| 32 | 38 | 2 | 546106 | 902188 | 295 | 204 |
| 32 | 38 | 3 | 546123 | 902190 | 250 | 163 |
| 32 | 39 | 1 | 546108 | 902134 | 251 | 169 |
| 32 | 39 | 2 | 546093 | 902137 | 260 | 290 |
| 32 | 39 | 3 | 546080 | 902140 | 251 | 166 |
| 32 | 40 | 1 | 546061 | 902086 | 261 | 180 |
| 32 | 40 | 2 | 546080 | 902085 | 268 | 188 |
| 32 | 40 | 3 | 546091 | 902082 | 251 | 170 |
| 32 | 41 | 1 | 546086 | 902015 | 229 | 159 |
| 32 | 41 | 2 | 546081 | 902022 | 225 | 162 |
| 32 | 41 | 3 | 546064 | 902027 | 249 | 175 |
| 32 | 42 | 1 | 546039 | 901963 | 227 | 152 |
| 32 | 42 | 2 | 546050 | 901964 | 209 | 143 |
| 32 | 42 | 3 | 546082 | 901970 | 230 | 144 |
| 32 | 43 | 1 | 546121 | 902031 | 274 | 31  |
| 32 | 43 | 2 | 546128 | 902034 | 294 | 34  |
| 32 | 43 | 3 | 546130 | 902040 | 294 | 205 |
| 32 | 44 | 1 | 546131 | 902027 | 236 | 166 |
| 32 | 44 | 2 | 546109 | 902030 | 221 | 156 |
| 32 | 44 | 3 | 546094 | 902036 | 200 | 146 |
| 32 | 45 | 1 | 546116 | 902081 | 229 | 149 |
| 32 | 45 | 2 | 546123 | 902084 | 246 | 171 |
| 32 | 45 | 3 | 546140 | 902085 | 243 | 170 |
| 32 | 46 | 1 | 546155 | 902132 | 267 | 179 |
| 32 | 46 | 2 | 546137 | 902035 | 151 | 174 |
| 32 | 46 | 3 | 546117 | 902025 | 272 | 187 |

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| 32 | 47 | 1 | 546132 | 902189 | 238 | 158 |
| 32 | 47 | 2 | 546146 | 902184 | 242 | 177 |
| 32 | 47 | 3 | 546160 | 902177 | 245 | 171 |
| 32 | 48 | 1 | 546140 | 902246 | 258 | 170 |
| 32 | 48 | 2 | 546156 | 902242 | 255 | 173 |
| 32 | 48 | 3 | 546166 | 902243 | 243 | 168 |
| 32 | 49 | 1 | 546184 | 902293 | 282 | 199 |
| 32 | 49 | 2 | 546170 | 902295 | 254 | 175 |
| 32 | 49 | 3 | 546145 | 902309 | 215 | 145 |
| 32 | 50 | 1 | 546166 | 902355 | 278 | 176 |
| 32 | 50 | 2 | 546180 | 902352 | 281 | 196 |
| 32 | 50 | 3 | 546197 | 902350 | 296 | 203 |
| 32 | 51 | 1 | 546204 | 902408 | 279 | 197 |
| 32 | 51 | 2 | 546181 | 902408 | 240 | 174 |
| 32 | 51 | 3 | 546168 | 902411 | 249 | 159 |
| 32 | 52 | 1 | 546195 | 902469 | 182 | 135 |
| 32 | 52 | 2 | 546205 | 902465 | 176 | 132 |
| 32 | 52 | 3 | 546214 | 902465 | 179 | 140 |
| 32 | 53 | 1 | 546239 | 902536 | 279 | 184 |
| 32 | 53 | 2 | 546226 | 902501 | 308 | 198 |
| 32 | 53 | 3 | 546222 | 902460 | 317 | 195 |
| 32 | 54 | 1 | 546221 | 902455 | 301 | 198 |
| 32 | 54 | 2 | 546217 | 902426 | 229 | 172 |
| 32 | 54 | 3 | 546212 | 902403 | 260 | 164 |
| 32 | 55 | 1 | 546211 | 902402 | 264 | 170 |
| 32 | 55 | 2 | 546204 | 902282 | 282 | 175 |
| 32 | 55 | 3 | 546199 | 902347 | 280 | 173 |
| 32 | 56 | 1 | 546197 | 902338 | 294 | 175 |
| 32 | 56 | 2 | 546195 | 902324 | 270 | 179 |
| 32 | 56 | 3 | 546187 | 902291 | 280 | 169 |
| 32 | 57 | 1 | 546185 | 902290 | 254 | 161 |
| 32 | 57 | 2 | 546182 | 902265 | 173 | 122 |
| 32 | 57 | 3 | 546178 | 902237 | 228 | 151 |
| 32 | 58 | 1 | 546175 | 902229 | 225 | 138 |
| 32 | 58 | 2 | 546166 | 902208 | 182 | 136 |
| 32 | 58 | 3 | 546164 | 902181 | 258 | 164 |
| 32 | 59 | 1 | 546163 | 902172 | 279 | 167 |
| 32 | 59 | 2 | 546158 | 902153 | 245 | 165 |
| 32 | 59 | 3 | 546153 | 902129 | 250 | 164 |
| 32 | 60 | 1 | 546151 | 902125 | 257 | 169 |
| 32 | 60 | 2 | 546148 | 902107 | 244 | 155 |
| 32 | 60 | 3 | 546143 | 902073 | 237 | 164 |
| 32 | 61 | 1 | 546141 | 902065 | 245 | 154 |
| 32 | 61 | 2 | 546127 | 902026 | 242 | 158 |
| 32 | 61 | 3 | 546124 | 901982 | 195 | 136 |
| 32 | 62 | 1 | 546171 | 901990 | 168 | 126 |
| 32 | 62 | 2 | 546166 | 902023 | 202 | 134 |

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| 32 | 62 | 3 | 546172 | 902056 | 210 | 144 |
| 32 | 63 | 1 | 546173 | 902062 | 212 | 152 |
| 32 | 63 | 2 | 546179 | 902084 | 223 | 153 |
| 32 | 63 | 3 | 546187 | 902113 | 207 | 152 |
| 32 | 64 | 1 | 546187 | 902119 | 204 | 143 |
| 32 | 64 | 2 | 546191 | 902145 | 220 | 155 |
| 32 | 64 | 3 | 546198 | 902173 | 201 | 134 |
| 32 | 65 | 1 | 546196 | 902179 | 185 | 140 |
| 32 | 65 | 2 | 546199 | 902198 | 97  | 72  |
| 32 | 65 | 3 | 546208 | 902231 | 210 | 147 |
| 32 | 66 | 1 | 546214 | 902234 | 198 | 135 |
| 32 | 66 | 2 | 546213 | 902261 | 219 | 148 |
| 32 | 66 | 3 | 546217 | 902282 | 230 | 163 |
| 32 | 67 | 1 | 546220 | 902287 | 230 | 161 |
| 32 | 67 | 2 | 546226 | 902311 | 218 | 147 |
| 32 | 67 | 3 | 546229 | 902340 | 234 | 159 |
| 32 | 68 | 1 | 546230 | 902348 | 232 | 155 |
| 32 | 68 | 2 | 546240 | 902382 | 235 | 158 |
| 32 | 68 | 3 | 546243 | 902402 | 236 | 166 |
| 32 | 69 | 1 | 546242 | 902404 | 246 | 168 |
| 32 | 69 | 2 | 546241 | 902424 | 238 | 156 |
| 32 | 69 | 3 | 546252 | 902458 | 259 | 164 |
| 32 | 70 | 1 | 546251 | 902460 | 283 | 174 |
| 32 | 70 | 2 | 546269 | 902481 | 272 | 179 |
| 32 | 70 | 3 | 546277 | 902519 | 296 | 205 |
| 32 | 71 | 1 | 546313 | 902521 | 230 | 162 |
| 32 | 71 | 2 | 546310 | 902492 | 235 | 151 |
| 32 | 71 | 3 | 546300 | 902454 | 250 | 163 |
| 32 | 72 | 1 | 546299 | 902450 | 240 | 161 |
| 32 | 72 | 2 | 546297 | 902428 | 232 | 157 |
| 32 | 72 | 3 | 546291 | 902391 | 247 | 164 |
| 32 | 73 | 1 | 546290 | 902380 | 220 | 238 |
| 32 | 73 | 2 | 546287 | 902360 | 238 | 148 |
| 32 | 73 | 3 | 546279 | 902336 | 230 | 156 |
| 32 | 74 | 1 | 546278 | 902331 | 215 | 141 |
| 32 | 74 | 2 | 546276 | 902318 | 220 | 145 |
| 32 | 74 | 3 | 546263 | 902285 | 199 | 127 |
| 32 | 75 | 1 | 546261 | 902280 | 208 | 135 |
| 32 | 75 | 2 | 546258 | 902261 | 203 | 135 |
| 32 | 75 | 3 | 546251 | 902232 | 203 | 138 |
| 32 | 76 | 1 | 546247 | 902229 | 174 | 115 |
| 32 | 76 | 2 | 546234 | 902200 | 105 | 79  |
| 32 | 76 | 3 | 546231 | 902181 | 224 | 152 |
| 32 | 77 | 1 | 546230 | 902175 | 210 | 139 |
| 32 | 77 | 2 | 546227 | 902150 | 210 | 145 |
| 32 | 77 | 3 | 546225 | 902118 | 207 | 142 |
| 32 | 78 | 1 | 546227 | 902111 | 190 | 128 |

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| 32 | 78 | 2 | 546226 | 902087 | 205 | 128 |
| 32 | 78 | 3 | 546221 | 902055 | 205 | 138 |
| 32 | 79 | 1 | 546219 | 902047 | 196 | 124 |
| 32 | 79 | 2 | 546212 | 902032 | 184 | 125 |
| 32 | 79 | 3 | 546206 | 901999 | 148 | 110 |
| 32 | 80 | 1 | 546239 | 902001 | 167 | 127 |
| 32 | 80 | 2 | 546247 | 902029 | 210 | 142 |
| 32 | 80 | 3 | 546252 | 902055 | 220 | 147 |
| 32 | 81 | 1 | 546255 | 902060 | 225 | 60  |
| 32 | 81 | 2 | 546258 | 902079 | 220 | 145 |
| 32 | 81 | 3 | 546266 | 902114 | 230 | 154 |
| 32 | 82 | 1 | 546267 | 902119 | 214 | 164 |
| 32 | 82 | 2 | 546269 | 902143 | 196 | 130 |
| 32 | 82 | 3 | 546273 | 902173 | 130 | 96  |
| 32 | 83 | 1 | 546272 | 902178 | 114 | 85  |
| 32 | 83 | 2 | 546277 | 902204 | 73  | 55  |
| 32 | 83 | 3 | 546286 | 902223 | 215 | 153 |
| 32 | 84 | 1 | 546284 | 902222 | 220 | 152 |
| 32 | 84 | 2 | 546293 | 902245 | 202 | 137 |
| 32 | 84 | 3 | 546303 | 902282 | 210 | 155 |
| 32 | 85 | 1 | 546303 | 902290 | 205 | 153 |
| 32 | 85 | 2 | 546304 | 902309 | 240 | 167 |
| 32 | 85 | 3 | 546308 | 902337 | 220 | 153 |
| 32 | 86 | 1 | 546307 | 902340 | 218 | 156 |
| 32 | 86 | 2 | 546311 | 902352 | 201 | 129 |
| 32 | 86 | 3 | 546323 | 902389 | 205 | 139 |
| 32 | 87 | 1 | 546323 | 902398 | 207 | 141 |
| 32 | 87 | 2 | 546329 | 902417 | 220 | 161 |
| 32 | 87 | 3 | 546332 | 902445 | 250 | 147 |
| 32 | 88 | 1 | 546334 | 902448 | 245 | 152 |
| 32 | 88 | 2 | 546341 | 902469 | 255 | 162 |
| 32 | 88 | 3 | 546349 | 902499 | 220 | 170 |
| 32 | 89 | 1 | 546384 | 902491 | 265 | 177 |
| 32 | 89 | 2 | 546380 | 902460 | 242 | 181 |
| 32 | 89 | 3 | 546377 | 902438 | 208 | 141 |
| 32 | 90 | 1 | 546375 | 902429 | 230 | 155 |
| 32 | 90 | 2 | 546373 | 902413 | 260 | 170 |
| 32 | 90 | 3 | 546369 | 902389 | 230 | 165 |
| 32 | 91 | 1 | 546368 | 902377 | 240 | 157 |
| 32 | 91 | 2 | 546361 | 902355 | 248 | 159 |
| 32 | 91 | 3 | 546358 | 902333 | 245 | 158 |
| 32 | 92 | 1 | 546357 | 902327 | 230 | 155 |
| 32 | 92 | 2 | 546349 | 902295 | 230 | 148 |
| 32 | 92 | 3 | 546346 | 902275 | 242 | 170 |
| 32 | 93 | 1 | 546348 | 902270 | 215 | 149 |
| 32 | 93 | 2 | 546336 | 902248 | 215 | 148 |
| 32 | 93 | 3 | 546329 | 902230 | 219 | 151 |



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| 32 | 94  | 1 | 546328 | 902221 | 220 | 156 |
| 32 | 94  | 2 | 546324 | 902198 | 215 | 154 |
| 32 | 94  | 3 | 546316 | 902170 | 220 | 148 |
| 32 | 95  | 1 | 546314 | 902163 | 243 | 169 |
| 32 | 95  | 2 | 546307 | 902130 | 210 | 148 |
| 32 | 95  | 3 | 546311 | 902112 | 120 | 85  |
| 32 | 96  | 1 | 546312 | 902110 | 103 | 80  |
| 32 | 96  | 2 | 546304 | 902084 | 83  | 70  |
| 32 | 96  | 3 | 546293 | 902046 | 105 | 75  |
| 32 | 97  | 1 | 546292 | 902038 | 145 | 38  |
| 32 | 97  | 2 | 546287 | 902014 | 160 | 14  |
| 32 | 97  | 3 | 546282 | 901991 | 205 | 135 |
| 32 | 98  | 1 | 546319 | 901984 | 118 | 96  |
| 32 | 98  | 2 | 546322 | 902008 | 168 | 11  |
| 32 | 98  | 3 | 546328 | 902032 | 208 | 32  |
| 32 | 99  | 1 | 546329 | 902037 | 230 | 156 |
| 32 | 99  | 2 | 546333 | 902056 | 237 | 164 |
| 32 | 99  | 3 | 546341 | 902094 | 235 | 162 |
| 32 | 100 | 1 | 546343 | 902098 | 236 | 160 |
| 32 | 100 | 2 | 546347 | 902117 | 242 | 171 |
| 32 | 100 | 3 | 546350 | 902140 | 251 | 181 |
| 32 | 101 | 1 | 546352 | 902149 | 235 | 157 |
| 32 | 101 | 2 | 546360 | 902178 | 235 | 154 |
| 32 | 101 | 3 | 546367 | 902204 | 249 | 174 |
| 32 | 102 | 1 | 546366 | 902211 | 250 | 177 |
| 32 | 102 | 2 | 546372 | 902242 | 229 | 157 |
| 32 | 102 | 3 | 546378 | 902272 | 237 | 161 |
| 32 | 103 | 1 | 546377 | 902283 | 241 | 172 |
| 32 | 103 | 2 | 546381 | 902302 | 238 | 165 |
| 32 | 103 | 3 | 546389 | 902323 | 235 | 160 |
| 32 | 104 | 1 | 546390 | 902327 | 237 | 157 |
| 32 | 104 | 2 | 546397 | 902352 | 230 | 161 |
| 32 | 104 | 3 | 546402 | 902380 | 235 | 181 |
| 32 | 105 | 1 | 546405 | 902385 | 230 | 171 |
| 32 | 105 | 2 | 546409 | 902412 | 235 | 165 |
| 32 | 105 | 3 | 546415 | 902439 | 250 | 171 |
| 32 | 106 | 1 | 546417 | 902447 | 245 | 161 |
| 32 | 106 | 2 | 546429 | 902495 | 235 | 171 |
| 32 | 106 | 3 | 546434 | 902522 | 242 | 169 |

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 89     | 1      | 1.1   | 542484 | 899785 | 78       | 73         |
| 89     | 1      | 1.2   | 542513 | 899788 | 65       | 41         |
| 89     | 1      | 1.3   | 542583 | 899769 | 68       | 66         |
| 89     | 1      | 1.4   | 542579 | 899813 | 68       | 67         |
| 89     | 1      | 1.5   | 542532 | 899814 | 64       | 60         |
| 89     | 1      | 1.6   | 542486 | 899812 | 77       | 70         |

|    |   |     |        |        |     |     |
|----|---|-----|--------|--------|-----|-----|
| 89 | 1 | 1.7 | 542479 | 899861 | 63  | 64  |
| 89 | 1 | 1.8 | 542517 | 899862 | 61  | 65  |
| 89 | 1 | 1.9 | 542586 | 899860 | 63  | 61  |
| 89 | 2 | 2.1 | 542584 | 899867 | 62  | 67  |
| 89 | 2 | 2.2 | 542516 | 899863 | 61  | 67  |
| 89 | 2 | 2.3 | 542479 | 899866 | 62  | 65  |
| 89 | 2 | 2.4 | 542491 | 899913 | 72  | 75  |
| 89 | 2 | 2.5 | 542529 | 899914 | 63  | 68  |
| 89 | 2 | 2.6 | 542581 | 899912 | 67  | 70  |
| 89 | 3 | 3.1 | 542588 | 899911 | 63  | 77  |
| 89 | 3 | 3.2 | 542680 | 899910 | 70  | 77  |
| 89 | 3 | 3.3 | 542680 | 899870 | 68  | 62  |
| 89 | 3 | 3.4 | 542592 | 899866 | 73  | 67  |
| 89 | 3 | 3.5 | 542592 | 899893 | 61  | 65  |
| 89 | 3 | 3.6 | 542682 | 899890 | 64  | 60  |
| 89 | 4 | 4.1 | 542595 | 899851 | 67  | 65  |
| 89 | 4 | 4.2 | 542686 | 899686 | 64  | 61  |
| 89 | 4 | 4.3 | 542689 | 899689 | 66  | 67  |
| 89 | 4 | 4.4 | 542598 | 899598 | 64  | 65  |
| 89 | 4 | 4.5 | 542594 | 899829 | 64  | 58  |
| 89 | 4 | 4.6 | 542689 | 899822 | 67  | 60  |
| 89 | 5 | 5.1 | 542600 | 899784 | 67  | 66  |
| 89 | 5 | 5.2 | 542690 | 899763 | 62  | 68  |
| 89 | 5 | 5.3 | 542688 | 899783 | 66  | 71  |
| 89 | 6 | 6.1 | 542706 | 899770 | 72  | 67  |
| 89 | 6 | 6.2 | 542793 | 899765 | 65  | 70  |
| 89 | 6 | 6.3 | 542796 | 899742 | 66  | 58  |
| 89 | 6 | 6.4 | 542702 | 899779 | 69  | 71  |
| 89 | 6 | 6.5 | 542755 | 899787 | 66  | 70  |
| 89 | 6 | 6.6 | 542753 | 899747 | 73  | 67  |
| 89 | 7 | 7.1 | 542703 | 899794 | 64  | 65  |
| 89 | 7 | 7.2 | 542787 | 899987 | 66  | 59  |
| 89 | 7 | 7.3 | 542790 | 899799 | 65  | 61  |
| 89 | 7 | 7.4 | 542696 | 899845 | 68  | 64  |
| 89 | 7 | 7.5 | 542699 | 899820 | 63  | 65  |
| 89 | 7 | 7.6 | 542792 | 899829 | 66  | 63  |
| 89 | 8 | 8.1 | 542696 | 899872 | 67  | 62  |
| 89 | 8 | 8.2 | 542779 | 899916 | 84  | 76  |
| 89 | 8 | 8.3 | 542777 | 899875 | 69  | 67  |
| 89 | 8 | 8.4 | 542695 | 899914 | 72  | 76  |
| 89 | 8 | 8.5 | 542694 | 899886 | 67  | 69  |
| 89 | 8 | 8.6 | 542783 | 899900 | 83  | 70  |
| 89 | 9 | 9.1 | 542801 | 899918 | 99  | 88  |
| 89 | 9 | 9.2 | 542887 | 899919 | 129 | 105 |
| 89 | 9 | 9.3 | 542890 | 899874 | 69  | 66  |
| 89 | 9 | 9.4 | 542807 | 899872 | 66  | 71  |
| 89 | 9 | 9.5 | 542803 | 899897 | 77  | 67  |

|    |    |      |        |        |    |    |
|----|----|------|--------|--------|----|----|
| 89 | 9  | 9.6  | 542890 | 899901 | 77 | 69 |
| 89 | 10 | 10.1 | 542807 | 899850 | 75 | 66 |
| 89 | 10 | 10.2 | 542889 | 899854 | 70 | 71 |
| 89 | 10 | 10.3 | 542895 | 899804 | 63 | 65 |
| 89 | 10 | 10.4 | 542808 | 899803 | 71 | 88 |
| 89 | 10 | 10.5 | 542809 | 899827 | 67 | 60 |
| 89 | 10 | 10.6 | 542897 | 899826 | 64 | 62 |
| 89 | 11 | 11.1 | 542811 | 899786 | 72 | 68 |
| 89 | 11 | 11.2 | 542897 | 899778 | 68 | 70 |
| 89 | 11 | 11.3 | 542902 | 899723 | 66 | 72 |
| 89 | 11 | 11.4 | 542810 | 899744 | 64 | 73 |
| 89 | 11 | 11.5 | 542819 | 899768 | 65 | 57 |
| 89 | 11 | 11.6 | 542900 | 899749 | 64 | 67 |

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 113    | 1      | 1     | 546311 | 907075 | 77       | 52         |
| 113    | 1      | 2     | 546317 | 907077 | 95       | 63         |
| 113    | 2      | 1     | 546316 | 907097 | 113      | 82         |
| 113    | 2      | 2     | 546301 | 907101 | 83       | 65         |
| 113    | 3      | 1     | 546288 | 907126 | 92       | 65         |
| 113    | 3      | 2     | 546294 | 907125 | 87       | 59         |
| 113    | 3      | 3     | 546308 | 907127 | 82       | 69         |
| 113    | 4      | 1     | 546311 | 907155 | 125      | 105        |
| 113    | 4      | 2     | 546293 | 907072 | 92       | 72         |
| 113    | 4      | 3     | 546275 | 907062 | 82       | 62         |
| 113    | 5      | 1     | 546280 | 907190 | 141      | 116        |
| 113    | 5      | 2     | 546292 | 907191 | 145      | 101        |
| 113    | 5      | 3     | 546318 | 907193 | 145      | 107        |
| 113    | 6      | 1     | 546308 | 907219 | 148      | 118        |
| 113    | 6      | 2     | 546290 | 907217 | 145      | 104        |
| 113    | 6      | 3     | 546271 | 907216 | 136      | 117        |
| 113    | 7      | 1     | 546272 | 907248 | 165      | 120        |
| 113    | 7      | 2     | 546295 | 907249 | 153      | 122        |
| 113    | 7      | 3     | 546303 | 907249 | 138      | 131        |
| 113    | 8      | 1     | 546298 | 907281 | 162      | 139        |
| 113    | 8      | 2     | 546277 | 907279 | 175      | 155        |
| 113    | 8      | 3     | 546263 | 907273 | 173      | 125        |
| 113    | 9      | 1     | 546303 | 907278 | 172      | 138        |
| 113    | 9      | 2     | 546318 | 907282 | 165      | 135        |
| 113    | 9      | 3     | 546240 | 907288 | 166      | 109        |
| 113    | 10     | 1     | 546340 | 907258 | 148      | 124        |
| 113    | 10     | 2     | 546330 | 907257 | 162      | 128        |
| 113    | 10     | 3     | 546309 | 907260 | 146      | 115        |
| 113    | 11     | 1     | 546310 | 907219 | 140      | 115        |
| 113    | 11     | 2     | 546329 | 907220 | 140      | 112        |
| 113    | 11     | 3     | 546346 | 907221 | 146      | 107        |
| 113    | 12     | 1     | 546347 | 907196 | 132      | 99         |

|     |    |   |        |        |     |     |
|-----|----|---|--------|--------|-----|-----|
| 113 | 12 | 2 | 546330 | 907198 | 129 | 92  |
| 113 | 12 | 3 | 546312 | 907195 | 139 | 103 |
| 113 | 13 | 1 | 546315 | 907165 | 127 | 86  |
| 113 | 13 | 2 | 546333 | 907167 | 110 | 91  |
| 113 | 13 | 3 | 546351 | 907169 | 115 | 76  |
| 113 | 14 | 1 | 546354 | 907137 | 92  | 70  |
| 113 | 14 | 2 | 546339 | 907136 | 113 | 88  |
| 113 | 14 | 3 | 546317 | 907134 | 94  | 75  |
| 113 | 15 | 1 | 546321 | 907103 | 116 | 84  |
| 113 | 15 | 2 | 546332 | 907102 | 64  | 40  |
| 113 | 15 | 3 | 546352 | 907104 | 31  | 17  |
| 113 | 15 | 4 | 546355 | 907102 | 34  | 22  |
| 113 | 16 | 1 | 546359 | 907072 | 112 | 75  |
| 113 | 16 | 2 | 546348 | 907074 | 109 | 78  |
| 113 | 16 | 3 | 546326 | 907047 | 107 | 74  |
| 113 | 17 | 1 | 546364 | 907059 | 81  | 62  |
| 113 | 17 | 2 | 546373 | 907056 | 78  | 56  |
| 113 | 17 | 3 | 546396 | 907056 | 92  | 65  |
| 113 | 18 | 1 | 546394 | 907077 | 94  | 71  |
| 113 | 18 | 2 | 546380 | 907083 | 89  | 59  |
| 113 | 18 | 3 | 546360 | 907076 | 95  | 66  |
| 113 | 19 | 1 | 546361 | 907107 | 38  | 34  |
| 113 | 19 | 2 | 546379 | 907108 | 51  | 43  |
| 113 | 19 | 3 | 546396 | 907111 | 95  | 67  |
| 113 | 20 | 1 | 546393 | 907138 | 106 | 85  |
| 113 | 20 | 2 | 546375 | 907140 | 102 | 86  |
| 113 | 20 | 3 | 546355 | 907143 | 93  | 67  |
| 113 | 21 | 1 | 546353 | 907105 | 124 | 105 |
| 113 | 21 | 2 | 546368 | 907164 | 100 | 94  |
| 113 | 21 | 3 | 546385 | 907161 | 98  | 75  |
| 113 | 22 | 1 | 546387 | 907201 | 137 | 130 |
| 113 | 22 | 2 | 546376 | 907203 | 124 | 108 |
| 113 | 22 | 3 | 546350 | 907198 | 129 | 105 |
| 113 | 23 | 1 | 546346 | 907230 | 145 | 119 |
| 113 | 23 | 2 | 546362 | 907233 | 153 | 116 |
| 113 | 23 | 3 | 546388 | 907232 | 143 | 117 |
| 113 | 24 | 1 | 546383 | 907263 | 160 | 144 |
| 113 | 24 | 2 | 546359 | 907260 | 158 | 123 |
| 113 | 24 | 3 | 546348 | 907259 | 160 | 119 |
| 113 | 25 | 1 | 546342 | 907288 | 157 | 122 |
| 113 | 25 | 2 | 546360 | 907293 | 171 | 119 |
| 113 | 25 | 3 | 546374 | 907295 | 169 | 131 |
| 113 | 26 | 1 | 546384 | 907293 | 157 | 127 |
| 113 | 26 | 2 | 546392 | 907294 | 167 | 140 |
| 113 | 26 | 3 | 546419 | 907295 | 155 | 134 |
| 113 | 27 | 1 | 546419 | 907266 | 163 | 127 |
| 113 | 27 | 2 | 546406 | 907263 | 163 | 141 |

|     |    |   |        |        |     |     |
|-----|----|---|--------|--------|-----|-----|
| 113 | 27 | 3 | 546381 | 907260 | 158 | 137 |
| 113 | 28 | 1 | 546386 | 907232 | 163 | 121 |
| 113 | 28 | 2 | 546403 | 907232 | 154 | 138 |
| 113 | 28 | 3 | 546427 | 907227 | 142 | 106 |
| 113 | 29 | 1 | 546427 | 907207 | 152 | 117 |
| 113 | 29 | 2 | 546410 | 907201 | 141 | 112 |
| 113 | 29 | 3 | 546390 | 907199 | 139 | 109 |
| 113 | 30 | 1 | 546391 | 907170 | 112 | 94  |
| 113 | 30 | 2 | 546408 | 907169 | 127 | 102 |
| 113 | 30 | 3 | 546427 | 907165 | 130 | 108 |
| 113 | 31 | 1 | 546431 | 907147 |     | 95  |
| 113 | 31 | 2 | 546415 | 907146 | 111 | 87  |
| 113 | 31 | 3 | 546394 | 907147 | 115 | 90  |
| 113 | 32 | 1 | 546400 | 907108 | 103 | 82  |
| 113 | 32 | 2 | 546418 | 907107 | 109 | 81  |
| 113 | 32 | 3 | 546434 | 907108 | 111 | 83  |
| 113 | 33 | 1 | 546435 | 907094 | 91  | 75  |
| 113 | 33 | 2 | 546422 | 907092 | 96  | 76  |
| 113 | 33 | 3 | 546405 | 907086 | 90  | 61  |
| 113 | 34 | 1 | 546405 | 907060 | 101 | 70  |
| 113 | 34 | 2 | 546420 | 907061 | 89  | 71  |
| 113 | 34 | 3 | 546446 | 907054 | 90  | 77  |
| 113 | 35 | 1 | 546470 | 907054 | 33  | 23  |
| 113 | 35 | 2 | 546456 | 907059 | 51  | 40  |
| 113 | 35 | 3 | 546441 | 907060 | 88  | 59  |
| 113 | 36 | 1 | 546437 | 907085 | 78  | 61  |
| 113 | 36 | 2 | 546452 | 907092 | 83  | 59  |
| 113 | 36 | 3 | 546466 | 907094 | 87  | 59  |
| 113 | 37 | 1 | 546468 | 907126 | 88  | 88  |
| 113 | 37 | 2 | 546453 | 907132 | 116 | 90  |
| 113 | 37 | 3 | 546439 | 907129 | 112 | 82  |
| 113 | 38 | 1 | 546436 | 907149 | 117 | 77  |
| 113 | 38 | 2 | 546450 | 907147 | 119 | 91  |
| 113 | 38 | 3 | 546470 | 907146 | 135 | 97  |
| 113 | 39 | 1 | 546467 | 907175 | 127 | 90  |
| 113 | 39 | 2 | 546448 | 907175 | 126 | 98  |
| 113 | 39 | 3 | 546433 | 907175 | 129 | 107 |
| 113 | 40 | 1 | 546430 | 907198 | 143 | 100 |
| 113 | 40 | 2 | 546449 | 907202 | 135 | 112 |
| 113 | 40 | 3 | 546462 | 907207 | 123 | 94  |
| 113 | 41 | 1 | 546462 | 907231 | 139 | 100 |
| 113 | 41 | 2 | 546444 | 907233 | 135 | 119 |
| 113 | 41 | 3 | 546427 | 907232 | 132 | 102 |
| 113 | 42 | 1 | 546424 | 907263 | 144 | 106 |
| 113 | 42 | 2 | 546441 | 907265 | 123 | 120 |
| 113 | 42 | 3 | 546460 | 907266 | 119 | 97  |
| 113 | 43 | 1 | 546454 | 907301 | 138 | 96  |

|     |    |   |        |        |     |     |
|-----|----|---|--------|--------|-----|-----|
| 113 | 43 | 2 | 546431 | 907297 | 141 | 102 |
| 113 | 43 | 3 | 546418 | 907293 | 160 | 119 |
| 113 | 44 | 1 | 546460 | 907298 | 124 | 100 |
| 113 | 44 | 2 | 546471 | 907301 | 110 | 83  |
| 113 | 44 | 3 | 546485 | 907304 | 104 | 84  |
| 113 | 45 | 1 | 546494 | 907275 | 109 | 74  |
| 113 | 45 | 2 | 546475 | 907269 | 132 | 117 |
| 113 | 45 | 3 | 546463 | 907263 | 125 | 94  |
| 113 | 46 | 1 | 546462 | 907239 | 126 | 111 |
| 113 | 46 | 2 | 546483 | 907240 | 115 | 95  |
| 113 | 46 | 3 | 546505 | 907242 | 103 | 90  |
| 113 | 47 | 1 | 546504 | 907212 | 96  | 70  |
| 113 | 47 | 2 | 546485 | 907208 | 108 | 95  |
| 113 | 47 | 3 | 546472 | 907207 | 111 | 97  |
| 113 | 48 | 1 | 546470 | 907182 | 126 | 104 |
| 113 | 48 | 2 | 546487 | 907181 | 101 | 102 |
| 113 | 48 | 3 | 546504 | 907178 | 100 | 81  |
| 113 | 49 | 1 | 546505 | 907158 | 100 | 81  |
| 113 | 49 | 2 | 546494 | 907151 | 118 | 89  |
| 113 | 49 | 3 | 546475 | 907149 | 121 | 88  |
| 113 | 50 | 1 | 546475 | 907119 | 100 | 67  |
| 113 | 50 | 2 | 546494 | 907116 | 101 | 75  |
| 113 | 50 | 3 | 546512 | 907121 | 96  | 79  |
| 113 | 51 | 1 | 546516 | 907096 | 87  | 59  |
| 113 | 51 | 2 | 546495 | 907096 | 82  | 64  |
| 113 | 51 | 3 | 546467 | 907091 | 77  | 61  |
| 113 | 52 | 1 | 546479 | 907058 | 44  | 56  |
| 113 | 52 | 2 | 546502 | 907052 | 58  | 39  |
| 113 | 52 | 3 | 546519 | 907056 | 41  | 41  |
| 113 | 53 | 1 | 546525 | 907058 | 35  | 34  |
| 113 | 53 | 2 | 546544 | 907059 | 48  | 35  |
| 113 | 53 | 3 | 546559 | 907061 | 56  | 44  |
| 113 | 54 | 1 | 546551 | 907096 | 99  | 81  |
| 113 | 54 | 2 | 546540 | 907095 | 101 | 78  |
| 113 | 54 | 3 | 546525 | 907096 | 110 | 69  |
| 113 | 55 | 1 | 546518 | 907117 | 93  | 82  |
| 113 | 55 | 2 | 546531 | 907120 | 119 | 99  |
| 113 | 55 | 3 | 546541 | 907124 | 104 | 87  |
| 113 | 56 | 1 | 546540 | 907161 | 121 | 105 |
| 113 | 56 | 2 | 546524 | 907154 | 110 | 116 |
| 113 | 56 | 3 | 546509 | 907149 | 106 | 89  |
| 113 | 57 | 1 | 546507 | 907179 | 125 | 98  |
| 113 | 57 | 2 | 546528 | 907185 | 101 | 94  |
| 113 | 57 | 3 | 546540 | 907189 | 110 | 94  |
| 113 | 58 | 1 | 546540 | 907212 | 101 | 92  |
| 113 | 58 | 2 | 546527 | 907211 | 107 | 97  |
| 113 | 58 | 3 | 546506 | 907209 | 104 | 84  |

|     |    |   |        |        |     |    |
|-----|----|---|--------|--------|-----|----|
| 113 | 59 | 1 | 546500 | 907241 | 115 | 85 |
| 113 | 59 | 2 | 546522 | 907244 | 85  | 66 |
| 113 | 59 | 3 | 546536 | 907249 | 92  | 83 |
| 113 | 60 | 1 | 546536 | 907235 | 91  | 71 |
| 113 | 60 | 2 | 546520 | 907276 | 53  | 35 |
| 113 | 60 | 3 | 546501 | 907280 | 103 | 74 |
| 113 | 61 | 1 | 546497 | 907306 | 96  | 71 |
| 113 | 61 | 2 | 546516 | 907305 | 75  | 62 |
| 113 | 61 | 3 | 546532 | 907308 | 125 | 94 |

| Parcel | Decimo | Point | x      | y      | Vertical | Horizontal |
|--------|--------|-------|--------|--------|----------|------------|
| 146    | 1      | 1     | 543348 | 905354 | 110      | 93         |
| 146    | 1      | 2     | 543364 | 905361 | 123      | 101        |
| 146    | 1      | 3     | 543366 | 905371 | 104      | 88         |
| 146    | 2      | 1     | 543368 | 905360 | 103      | 87         |
| 146    | 2      | 2     | 543387 | 905375 | 157      | 118        |
| 146    | 2      | 3     | 543398 | 905381 | 155      | 117        |
| 146    | 2      | 4     | 543409 | 905388 | 170      | 128        |
| 146    | 3      | 1     | 543411 | 905393 | 159      | 119        |
| 146    | 3      | 2     | 543418 | 905397 | 154      | 116        |
| 146    | 3      | 3     | 543427 | 905409 | 158      | 117        |
| 146    | 3      | 4     | 543444 | 905417 | 281      | 221        |
| 146    | 3      | 5     | 543443 | 905423 | 211      | 169        |
| 146    | 3      | 6     | 543473 | 905435 | 252      | 254        |
| 146    | 3      | 7     | 543458 | 905427 | 317      | 266        |
| 146    | 3      | 8     | 543462 | 905422 | 302      | 254        |
| 146    | 3      | 9     | 543456 | 905433 | 133      | 271        |
| 146    | 4      | 1     | 543476 | 905472 | 238      | 229        |
| 146    | 4      | 2     | 543492 | 905429 | 255      | 210        |
| 146    | 4      | 3     | 543506 | 905455 | 206      | 165        |
| 146    | 4      | 4     | 543520 | 905467 | 232      | 202        |
| 146    | 4      | 5     | 543539 | 905477 | 225      | 170        |
| 146    | 5      | 1     | 543542 | 905483 | 232      | 190        |
| 146    | 5      | 2     | 543554 | 905491 | 261      | 211        |
| 146    | 5      | 3     | 543569 | 905502 | 245      | 170        |
| 146    | 5      | 4     | 543583 | 905512 | 198      | 153        |
| 146    | 5      | 5     | 543597 | 905529 | 196      | 125        |
| 146    | 6      | 1     | 543606 | 905528 | 168      | 122        |
| 146    | 6      | 2     | 543618 | 905537 | 229      | 182        |
| 146    | 6      | 3     | 543633 | 905547 | 127      | 185        |
| 146    | 6      | 4     | 543649 | 905556 | 206      | 115        |
| 146    | 6      | 5     | 543660 | 905564 | 167      | 125        |
| 146    | 6      | 6     | 543670 | 905571 | 135      | 101        |
| 146    | 6      | 7     | 543674 | 905578 | 162      | 121        |
| 146    | 7      | 1     | 543643 | 905646 | 137      | 112        |
| 146    | 7      | 2     | 543636 | 905630 | 205      | 149        |
| 146    | 7      | 3     | 543633 | 905614 | 204      | 163        |

|     |    |   |        |        |     |     |
|-----|----|---|--------|--------|-----|-----|
| 146 | 7  | 4 | 543630 | 905598 | 223 | 173 |
| 146 | 7  | 5 | 543626 | 905582 | 264 | 235 |
| 146 | 7  | 6 | 543624 | 905559 | 260 | 145 |
| 146 | 7  | 7 | 543615 | 905545 | 229 | 186 |
| 146 | 8  | 1 | 543604 | 905522 | 202 | 150 |
| 146 | 8  | 2 | 543609 | 905563 | 232 | 190 |
| 146 | 8  | 3 | 543612 | 905586 | 235 | 192 |
| 146 | 8  | 4 | 543618 | 905600 | 204 | 165 |
| 146 | 8  | 5 | 543621 | 905633 | 194 | 141 |
| 146 | 8  | 6 | 543636 | 905663 | 215 | 151 |
| 146 | 9  | 1 | 543615 | 905704 | 182 | 135 |
| 146 | 9  | 2 | 543614 | 905679 | 220 | 157 |
| 146 | 9  | 3 | 543608 | 905662 | 181 | 133 |
| 146 | 9  | 4 | 543597 | 905619 | 217 | 157 |
| 146 | 9  | 5 | 543589 | 905598 | 210 | 157 |
| 146 | 9  | 6 | 543581 | 905566 | 184 | 144 |
| 146 | 10 | 1 | 543572 | 905568 | 193 | 152 |
| 146 | 10 | 2 | 543573 | 905536 | 178 | 140 |
| 146 | 10 | 3 | 543570 | 905514 | 217 | 175 |
| 146 | 10 | 4 | 543572 | 905508 | 251 | 208 |
| 146 | 10 | 5 | 543562 | 905522 | 185 | 136 |
| 146 | 10 | 6 | 543565 | 905541 | 168 | 131 |
| 146 | 10 | 7 | 543571 | 905564 | 200 | 147 |
| 146 | 11 | 1 | 543572 | 905578 | 107 | 140 |
| 146 | 11 | 2 | 543575 | 905599 | 208 | 158 |
| 146 | 11 | 3 | 543584 | 905620 | 210 | 161 |
| 146 | 11 | 4 | 543600 | 905657 | 195 | 153 |
| 146 | 11 | 5 | 543603 | 905686 | 209 | 153 |
| 146 | 11 | 6 | 543605 | 905713 | 170 | 122 |
| 146 | 12 | 1 | 543585 | 905758 | 141 | 102 |
| 146 | 12 | 2 | 543581 | 905743 | 161 | 121 |
| 146 | 12 | 3 | 543571 | 905708 | 203 | 135 |
| 146 | 12 | 4 | 543572 | 905672 | 224 | 165 |
| 146 | 12 | 5 | 543566 | 905645 | 202 | 155 |
| 146 | 12 | 6 | 543571 | 905618 | 160 | 113 |
| 146 | 13 | 1 | 543550 | 905610 | 191 | 138 |
| 146 | 13 | 2 | 543541 | 905578 | 192 | 153 |
| 146 | 13 | 3 | 543534 | 905548 | 244 | 187 |
| 146 | 13 | 4 | 543537 | 905513 | 246 | 198 |
| 146 | 13 | 5 | 543531 | 905494 | 211 | 160 |
| 146 | 14 | 1 | 543499 | 905537 | 244 | 195 |
| 146 | 14 | 2 | 543496 | 905520 | 224 | 172 |
| 146 | 14 | 3 | 543486 | 905501 | 210 | 161 |
| 146 | 14 | 4 | 543485 | 905478 | 222 | 180 |
| 146 | 14 | 5 | 543475 | 905452 |     |     |
| 146 | 15 | 1 | 543490 | 905555 | 245 | 202 |
| 146 | 15 | 2 | 543509 | 905582 | 206 | 146 |



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| 146 | 15 | 3 | 543517 | 905618 | 216 | 166 |
| 146 | 15 | 4 | 543528 | 905622 | 218 | 170 |
| 146 | 16 | 1 | 543527 | 905671 | 184 | 133 |
| 146 | 16 | 2 | 543537 | 905719 | 182 | 128 |
| 146 | 16 | 3 | 543541 | 905741 | 183 | 122 |
| 146 | 16 | 4 | 543562 | 905804 | 86  | 66  |
| 146 | 17 | 1 | 543557 | 905811 | 101 | 85  |
| 146 | 17 | 2 | 543554 | 905762 | 139 | 104 |
| 146 | 17 | 3 | 543535 | 905725 | 165 | 110 |
| 146 | 17 | 4 | 543514 | 905688 | 184 | 133 |
| 146 | 18 | 1 | 543521 | 905688 | 202 | 151 |
| 146 | 18 | 2 | 543511 | 905644 | 200 | 145 |
| 146 | 18 | 3 | 543498 | 905602 | 191 | 138 |
| 146 | 18 | 4 | 543494 | 905570 | 163 | 128 |
| 146 | 19 | 1 | 543495 | 905556 | 219 | 175 |
| 146 | 19 | 2 | 543488 | 905523 | 194 | 155 |
| 146 | 19 | 3 | 543483 | 905487 | 171 | 161 |
| 146 | 19 | 4 | 543473 | 905475 | 160 | 150 |
| 146 | 20 | 1 | 543424 | 905391 | 127 | 99  |
| 146 | 20 | 2 | 543443 | 905428 | 233 | 111 |
| 146 | 20 | 3 | 543434 | 905442 | 254 | 215 |
| 146 | 20 | 4 | 543446 | 905493 | 152 | 155 |
| 146 | 21 | 1 | 543448 | 905504 | 46  | 48  |
| 146 | 21 | 2 | 543453 | 905523 | 166 | 160 |
| 146 | 21 | 3 | 543460 | 905487 | 206 | 173 |
| 146 | 21 | 4 | 543468 | 905475 | 191 | 150 |
| 146 | 22 | 1 | 543472 | 905614 | 200 | 147 |
| 146 | 22 | 2 | 543475 | 905633 | 186 | 139 |
| 146 | 22 | 3 | 543478 | 905667 | 166 | 114 |
| 146 | 22 | 4 | 543489 | 905699 | 175 | 119 |
| 146 | 23 | 1 | 543495 | 905713 | 175 | 133 |
| 146 | 23 | 2 | 543487 | 905584 | 163 | 116 |
| 146 | 23 | 3 | 543481 | 905647 | 218 | 147 |
| 146 | 23 | 4 | 543473 | 905621 | 185 | 143 |
| 146 | 24 | 1 | 543470 | 905602 | 167 | 124 |
| 146 | 24 | 2 | 543457 | 905657 | 216 | 170 |
| 146 | 24 | 3 | 543447 | 905530 | 203 | 170 |
| 146 | 24 | 4 | 543445 | 905501 | 51  | 55  |
| 146 | 25 | 1 | 543443 | 905477 | 182 | 163 |
| 146 | 25 | 2 | 543433 | 905445 | 255 | 210 |
| 146 | 25 | 3 | 543428 | 905415 | 206 | 159 |
| 146 | 25 | 4 | 543424 | 905380 | 168 | 122 |
| 146 | 26 | 1 | 543366 | 905362 | 92  | 85  |
| 146 | 26 | 2 | 543376 | 905376 | 89  | 82  |
| 146 | 26 | 3 | 543380 | 905416 | 93  | 92  |
| 146 | 26 | 4 | 543386 | 905442 | 73  | 68  |
| 146 | 27 | 1 | 543490 | 905498 | 100 | 93  |

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| 146 | 27 | 2 | 543397 | 905478 | 189 | 139 |
| 146 | 27 | 3 | 543401 | 905496 | 111 | 90  |
| 146 | 27 | 4 | 543410 | 905540 | 44  | 69  |
| 146 | 28 | 1 | 543415 | 905548 | 118 | 98  |
| 146 | 28 | 2 | 543414 | 905570 | 225 | 178 |
| 146 | 28 | 3 | 543421 | 905588 | 203 | 144 |
| 146 | 28 | 4 | 543429 | 905628 | 186 | 135 |
| 146 | 29 | 1 | 543440 | 905643 | 219 | 169 |
| 146 | 29 | 2 | 543454 | 905651 | 201 | 156 |
| 146 | 29 | 3 | 543462 | 905718 | 142 | 112 |
| 146 | 29 | 4 | 543464 | 905771 | 143 | 113 |
| 146 | 30 | 1 | 543453 | 905732 | 161 | 120 |
| 146 | 30 | 2 | 543447 | 905709 | 186 | 145 |
| 146 | 30 | 3 | 543438 | 905670 | 198 | 143 |
| 146 | 30 | 4 | 543434 | 905655 | 234 | 175 |
| 146 | 31 | 1 | 543432 | 905432 | 193 | 153 |
| 146 | 31 | 2 | 543428 | 905428 | 126 | 165 |
| 146 | 31 | 3 | 543423 | 905423 | 222 | 164 |
| 146 | 31 | 4 | 543413 | 905413 | 93  | 87  |
| 146 | 32 | 1 | 543409 | 905537 | 41  | 45  |
| 146 | 32 | 2 | 543403 | 905503 | 44  | 45  |
| 146 | 32 | 3 | 543397 | 905466 | 167 | 122 |
| 146 | 32 | 4 | 543389 | 905436 | 91  | 78  |
| 146 | 33 | 1 | 543388 | 905426 | 75  | 74  |
| 146 | 33 | 2 | 543381 | 905394 | 105 | 95  |
| 146 | 33 | 3 | 543373 | 905367 | 94  | 93  |
| 146 | 33 | 4 | 543370 | 905353 | 99  | 88  |
| 146 | 34 | 1 | 543374 | 905405 | 101 | 95  |
| 146 | 34 | 2 | 543379 | 905412 | 98  | 85  |
| 146 | 34 | 3 | 543390 | 905430 | 96  | 96  |
| 146 | 34 | 4 | 543403 | 905438 | 111 | 101 |
| 146 | 35 | 1 | 543333 | 905379 | 66  | 63  |
| 146 | 35 | 2 | 543339 | 905397 | 64  | 64  |
| 146 | 35 | 3 | 543363 | 905469 | 89  | 73  |
| 146 | 35 | 4 | 543364 | 905482 | 71  | 66  |
| 146 | 36 | 1 | 543332 | 905383 | 53  | 54  |
| 146 | 36 | 2 | 543340 | 905405 | 59  | 57  |
| 146 | 36 | 3 | 543368 | 905481 | 80  | 72  |
| 146 | 36 | 4 | 543375 | 905485 | 83  | 91  |
| 146 | 37 | 1 | 543358 | 905489 | 65  | 62  |
| 146 | 37 | 2 | 543356 | 905491 | 78  | 70  |
| 146 | 37 | 3 | 543360 | 905493 | 76  | 71  |
| 146 | 37 | 4 | 543361 | 905502 | 116 | 94  |
| 146 | 38 | 1 | 543369 | 905502 | 137 | 110 |
| 146 | 38 | 2 | 543368 | 905530 | 170 | 136 |
| 146 | 38 | 3 | 543379 | 905534 | 240 | 182 |
| 146 | 38 | 4 | 543381 | 905581 | 204 | 136 |

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| 146 | 39 | 1 | 543382 | 905587 | 176 | 135 |
| 146 | 39 | 2 | 543379 | 905601 | 213 | 153 |
| 146 | 39 | 3 | 543383 | 905633 | 190 | 144 |
| 146 | 39 | 4 | 543384 | 905639 | 214 | 163 |
| 146 | 40 | 1 | 543393 | 905656 | 182 | 139 |
| 146 | 40 | 2 | 543396 | 905664 | 219 | 168 |
| 146 | 40 | 3 | 543387 | 905675 | 203 | 151 |
| 146 | 40 | 4 | 543406 | 905698 | 208 | 160 |
| 146 | 41 | 1 | 543390 | 905686 | 194 | 151 |
| 146 | 41 | 2 | 543383 | 905679 | 194 | 157 |
| 146 | 41 | 3 | 543362 | 905666 | 221 | 161 |
| 146 | 41 | 4 | 543352 | 905658 | 245 | 193 |
| 146 | 42 | 1 | 543353 | 905643 | 226 | 167 |
| 146 | 42 | 2 | 543352 | 905636 | 249 | 188 |
| 146 | 42 | 3 | 543342 | 905621 | 215 | 168 |
| 146 | 42 | 4 | 543341 | 905614 | 190 | 139 |
| 146 | 43 | 1 | 543339 | 905597 | 166 | 123 |
| 146 | 43 | 2 | 543338 | 905589 | 232 | 165 |
| 146 | 43 | 3 | 543331 | 905566 | 213 | 154 |
| 146 | 43 | 4 | 543326 | 905521 | 143 | 113 |
| 146 | 44 | 1 | 543327 | 905534 | 162 | 118 |
| 146 | 44 | 2 | 543326 | 905532 | 186 | 124 |
| 146 | 44 | 3 | 543321 | 905516 | 94  | 88  |
| 146 | 44 | 4 | 543320 | 905498 | 84  | 73  |
| 146 | 45 | 1 | 543312 | 905470 | 52  | 50  |
| 146 | 45 | 2 | 543309 | 905458 | 48  | 45  |
| 146 | 45 | 3 | 543308 | 905441 | 68  | 58  |
| 146 | 45 | 4 | 543309 | 905437 | 95  | 81  |
| 146 | 46 | 1 | 543292 | 905466 | 77  | 67  |
| 146 | 46 | 2 | 543291 | 905475 | 60  | 56  |
| 146 | 46 | 3 | 543293 | 905491 | 76  | 68  |
| 146 | 46 | 4 | 543290 | 905502 | 87  | 73  |
| 146 | 47 | 1 | 543288 | 905588 | 105 | 84  |
| 146 | 47 | 2 | 543287 | 905550 | 110 | 85  |
| 146 | 47 | 3 | 543302 | 905578 | 157 | 108 |
| 146 | 47 | 4 | 543304 | 905589 | 194 | 146 |
| 146 | 48 | 1 | 543294 | 905614 | 171 | 120 |
| 146 | 48 | 2 | 543299 | 905620 | 145 | 114 |
| 146 | 48 | 3 | 543309 | 905625 | 217 | 174 |
| 146 | 48 | 4 | 543315 | 905631 | 250 | 205 |
| 146 | 49 | 1 | 543262 | 905602 | 161 | 129 |
| 146 | 49 | 2 | 543263 | 905593 | 224 | 166 |
| 146 | 49 | 3 | 543253 | 905588 | 164 | 115 |
| 146 | 49 | 4 | 543231 | 905567 | 100 | 82  |